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Clearing Land & Rocks *for* Agricultural and Other Purposes

By J. R. MATTERN

Published by
The Institute of Makers of Explosives
Room 902, 103 Park Ave., New York



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OF
MAKERS OF EXPLOSIVES

Organized July 15, 1913

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How weeds and briars grow up about a boulder in a field. In this case the stone itself is not very large, but the total land area put out of business is three times as much as the stone covers.

INTRODUCTORY

THIS bulletin is published by the Institute of Makers of Explosives. The aim is to give the united conclusions and the sum of the experience to date of nearly all makers of explosives and of farmers who have dealt successfully with the problem of boulders and ledges in their fields.

The material has been classified and assembled so any phase of it will be available easily and quickly. Uncertainties have been eliminated as much as possible in favor of known facts and formulas established by actual experience. It is offered as a manual or handbook for farmers, home and road builders, contractors, park makers and others who must remove rocks from land, and as a textbook for students of agriculture.

Readers will find that the recommendations are impartial, and that the suggestions on that part of the work which can be done best with explosives are particularly complete.

Boulders and Ledges of Rock

Eight generations of farmers have picked stones off the fields of a great many farms in this country, and in these same fields all the boulders too big to be moved by the direct strength of men and horses still are dodged by the present farmers. Some land cleared and farmed as long ago as the Revolutionary War has not had the "niggerheads" removed to this day.

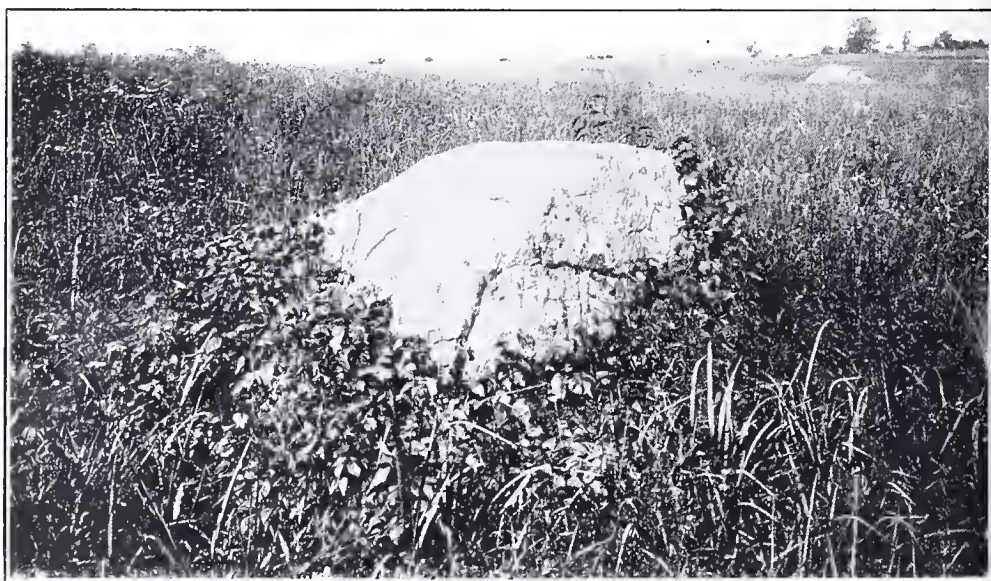
Those stones that project above the surface of the ground can be avoided, but those hidden underneath are more serious trouble makers. The man who works his own land for years gets to know where they lie, and can escape them to a certain extent, but it is by broken plowshares that a new plowman learns their location.

In former years, before the value of land began to increase as it has of late years, farmers found more profit in locating a new acre that had fewer stones or none at all than in removing those from a stony acre. But that time is past. Farm land today can be made to pay without removing the boulders, but not the full hundred cents from each dollar earned by the work and expense put on it. Stony farms can be sold, but not for big prices. Thoughtful farmers remove the rocks.

It is surprising how much there is to know about the disposal of boulders. Too often this work has been attempted in ways that were crude and wasteful of energy and time, and considering these items, very expensive. This is partly due to the lack of published data describing easier, simpler ways. The up-to-date farmer will not tolerate methods that are wasteful or unprofitable. He may find the information he wants in the following pages.

The Profit and Loss Account of Boulders

The interference of boulders and rock ledges with farming operations and profits takes many forms, and its cost can be estimated from a glance at a few of them.



This is the sort of perpetual tenant which pays no rent, and on which this bulletin declares war.

On ground where a cultivated crop is grown, each boulder causes the waste and loss of about half an hour per year of the time of a man with a team, worth five dollars a day. Four seasons' loss will remove the stones. They "eat their heads off" as the saying goes, ten or more times during the active lifetime of the average generation.

In addition, the breakage and damage to tools and machines may amount to as much in total loss as that from waste of time. This is particularly true of those farms where modern heavy implements are used, as, for instance, the heavy disc harrows for four or more horses, the gang plows, and all the tillage tools pulled by traction engines. Tractor plows and harrows are sure to be broken in stumpy or rocky land. It is impossible to make good time with gang plows or harrows among boulders, because of the constant stopping necessary, and besides, the work done is bound to be poor. Ten to twenty boulders to the acre are just about as bad as 100 for the man with the engine implements—they make good work and speedy work impossible.

About each rock that sticks above the surface some weeds are sure to grow. There never is the stone, or log, or stump, on or in the ground but where you can find a thistle or two, or several specimens of other equally noxious plants, growing close to the edge or out from under it. These single weeds re-seed entire fields.

Another feature of the loss sometimes caused by tight stones in fields is the injury to horses and men caused by the sudden strain and jerks. Horses

Danger to Horse and Men sprain leg joints, shoulders, hips and backs. Many spavins have their beginning in the ugly twists sustained. Brood mares often are caused to lose their foals prematurely. The baffling for which stones are responsible is

one of the most common causes of balkiness of farm horses. A team can be ruined in a short time by such treatment.

The danger to men is not so common, but when it does come it comes heavily. The records of the past generation show that many a farmer was struck with a plow handle when the plow point encountered a stone that was tight. Sometimes the result is a broken arm or hip, or rib, or worse still, a rupture. The newspapers frequently report accidents caused by the driver of a mowing machine being thrown from the seat into the knives, or under the heels of the horses, when the machine suddenly struck tight obstructions such as stones.

The direct loss of crops which would grow on the land occupied by the boulders need not be stated in figures. Every farmer knows that the loss of corn, wheat, or hay on a square rod amounts to 15 to 50 cents a year.

Low Land Value and Increase Tight stones on a farm are bound to keep its selling value down. One of the first things a shrewd buyer of land will want to know is whether the soil is free of rocks that interfere with cultivation. One of the easiest and surest ways of increasing the value of land, for selling, for actual use, and in the estimation of other people, is to clear away the boulders.

The stones themselves may not be without value when they are broken up in pieces small enough to handle. It is well for every farm to have a pile in some convenient place, where they can be had any time they are wanted. They are valuable for building material, and in drains and walks. At the rates prevailing in many places it is easy to collect fifty dollars' worth of stone right

near where it is needed and save both the cost of the stone and most of the expense of hauling.

Some of the more common purposes for which stones are valuable on farms are for blind drains, for lining ditches along roads or in fields, where the water gouges out the sides or bottom on account of a grade or turn, for road foundations, for repairs to walks, for constructing steps, chimneys, walls, etc., for filling in concrete construction, and for building garages, houses, barns and silos.

Clearing land of boulders should not be regarded as an expense, like taxes, or like the cost of shoes to wear. It is an investment, like the purchase of Government bonds, or like the purchase of shoes by a storekeeper, to sell again. When money is spent for removing boulders by a farmer, he is buying something—the clean land—that at once begins to pay back the cost of the work. It pays for itself within three or four years and then keeps right on paying dividends year by year.

Kinds of Rock and Their Nature

It helps if you know your rock when you go to break it up, for many different kinds exist as boulders and ledges on farms and in roads. In some sections the term "hardhead" is used to describe one kind of boulder. Another term is "niggerhead." It is better to know the rocks by the names which designate their real nature.

Rock Qualities

What does make a difference is that some stones are easy to break and others are not. To understand why, a study of the stones is necessary. Their resistance depends on their comparative hardness and toughness. These two qualities must not be confused, for they are not the same.

Hardness and Toughness To illustrate, window glass is hard, but not tough. It will scratch very hard steel, but will shatter under a light blow. Untempered iron is tough, but not hard. It can be ground away rapidly by a stone, or scratched with glass, but it is extremely difficult to break by pounding or twisting.

To some extent stones possess the same qualities, and in addition almost all of them have one or more lines of weakness. Most rocks have a grain, not unlike the grain of wood, and will split more easily along the grain, and less easily in any other direction. It is safe to say that all rocks have joints running in one direction, and some rocks have two sets of joints running at right angles. The joint lines may not be visible, but the force of a blast or of a sledge will find them. There is still another sort of weakness in rocks with which the blaster should be familiar. This is the bedding plane, or layer—with lines running at right angles to both joint-lines mentioned.

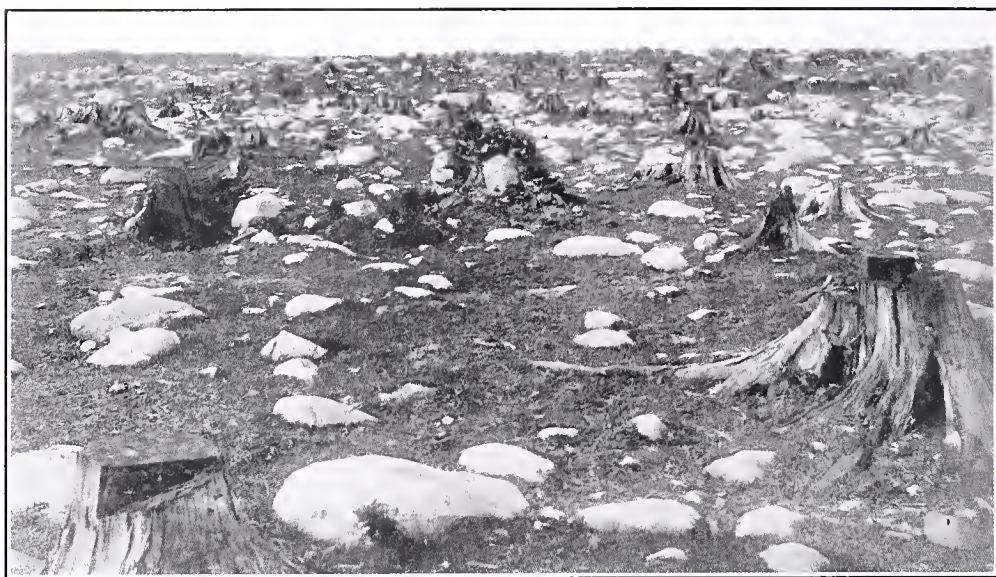
Some knowledge about the joints and natural cleavage planes makes the breaking of rocks easier. Even the most massive rocks are divided into blocks of varying sizes, making them split in some directions easier than in others. The cracks will tend to stop short and splinter out or to run entirely through the stones, depending on the toughness of the rock, while the blocks will or will not crumble much according to their hardness.



How the seam and joint lines crisscross in most stones. A little inspection of a stone nearly always will show a spot where the force can be applied to break it with much less force or greater effectiveness than if the stone is attacked at solid spots.

Description of Rocks

In these brief remarks we will make no attempt to give the geological classification of the rocks, but will try to identify the typical rocks found as boulders and ledges by names which are used most generally, and to make



Two fields which will cost \$50 to \$200 or more an acre to clear of stumps and stones. If the land can be used for residential purposes or for some form of intensive farming like trucking or fruit growing, it will pay to clear such places, but it will not pay to clear them for general farming and pasture purposes.

clear their nature. Common names for different kinds of rock or stone are not always satisfactory because the common name applied generally to one kind of rock in certain localities in numerous instances is applied to an entirely different kind of rock in other localities, but it is hoped that any confusion will be limited.

These three classes of rock seldom exist as boulders, though they sometimes interfere with cultivation in the form of ledges close to the surface of the ground. In this shape they nearly always are full of two sets of joints, and lie in thin beds. Sometimes the seams are so close together that the rock breaks up into blocks only an inch or two square. They are fairly tough, are inclined to crumble rather than split or crack, when struck with a sledge hammer, and are easy to drill.

Usually takes the form of flat boulders on the surface in fields or of ledges which project almost to the surface or above the surface several feet. Limestone generally has two systems of joints. It also has bed lines wide apart—a foot or more. This kind of stone nearly always is tough, breaking off, rather than splitting far. Its hardness varies.

The boulders of this class frequently are nearly round. Slate rock is characterized by a thin shingle structure. The leaves are less than a quarter of an inch thick. There are joints as well. The stone is tough, breaking only a short distance (but splitting on cleavage lines easily), soft, and inclined to crumble.

Occurs as boulders of every shape and size, and as ledges of all sorts. The ledges usually are stratified—that is, in beds of a thickness of one, 2, 3 or more



See picture on preceding page

feet. It has frequent joint lines running in two directions, and it breaks up into irregular sized blocks of more or less rectangular shape. The **Sandstone** sand particles which compose the stone are very hard. When the cementing material is silica the stone is blue or white, and much harder than when of an iron origin, making a brown or red stone. For purposes of drilling, blue sandstone must be classified as a hard rock, and brown sandstone as softer rock; and for breaking purposes, both kinds may be listed as soft. It crumbles easily, and is rather tough.

These rocks and others like them in structure lie **Lava, Mica Rocks,** in layers from 2 to 100 feet thick. They have no other bed lines, but they have infrequent joint lines. **Feldspar**

Lava, excepting that of the pumice type, is hard and brittle. The boulders split fairly easily into pieces of irregular shape and size.

A mixture of various rocks, such as slate, sandstone and the like, often in the form of pebbles cemented together, making a rock that lies in beds. It may be crystalline and very hard—even flinty—or it may be **Conglomerate** only medium hard. The boulders are rather brittle than tough. Joints in one direction are located wide apart. Boulders of conglomerate rock sometimes have a ball-like structure, with layer after layer 1 to 6 inches thick, and joints every 2 to 4 inches. The layers of such rock crack off like the skin of an onion.

Occurs often as boulders, though frequently there are granite **Granite** ledges. Granite is of a layer structure, with frequent joints. It splits easily. It is not particularly tough, and is hard to drill. Some granite breaks easily while other is difficult to shatter.

These rocks are very different and can only be classified together when referring to methods of breaking them. They are fine-grained, and have no distinct bedding planes. They do not break up in layers. They do break along joint lines. They are sometimes quite hard, but not very tough, and except trap rock, which is tough, often shatter easily. The boulders are numerous in some sections of the country, and ledges are not infrequent.

Some rocks are full of irregular cavities resembling bubbles, and these generally make the breaking easier. The cavities interfere with the regular joint lines and cause the splitting to take place along new lines of weakness.

The amount of force required to break a rock depends on its hardness and its relative toughness, and on the lines of weakness or cleavage which run through it. Hard rocks usually crumble less easily than soft rocks, but generally split better when once started. Tough rocks are hard to split into small pieces, while brittle ones shatter to bits under a proper blow.

The point at which the force should be applied for the most and quickest breakage depends on the structure of the rock and the direction and frequency of bedding and joint lines.

Methods of Clearing Away Rocks

Rocks too large to be pried out and loaded for hauling by hand, and tight ledges, must be broken. Following is described eight methods of breaking them. Each method has advantages under certain conditions, but some are much more serviceable, convenient and easy than others under most circumstances.

List of Methods

Eight Methods Hauling: Consists of either dragging with chains or loading on sled or wagon. See page 31.

Sledging: Consists of hammering them into pieces small enough to handle. See page 14.

Burying: Needs no description. See page 14.

Breaking with fire: It is possible to break many kinds of rocks in this way. See page 14.

Plug and feather breaking: Intended for splitting out building stone. Consists of drilling a series of small holes in a line across a boulder, and then driving into these holes special steel wedges.

Blasting by drilling: Called "blockholing" when referring to boulders. See page 23.

Blasting by undermining or underdrilling: Called "undermine blasting" or "snakeholing." See page 19.

Blasting by mudcapping: Also called "doby shooting," "plastering" or "blistering." See page 15.

Choice of a Method

Cost, Men, Time and other Factors In the practical handling of rock clearing, the elements to be considered are the costs of labor and material required. These are governed by the nature and amount of rock to be broken. Time is also an important factor.

The softer and more brittle boulders, if they are not large, may be disposed of by any of the above methods. Very hard and tough rock cannot be



How a boulder can mar the appearance of a farm from the roadside view. Such a stone leads possible buyers of a place to think that the field contains many such.



The disposal of this partly buried boulder called for rolling it out of its bed in the ground without breaking it, and then mudcapping it. It was rolled out with one stick from the position shown in the first picture, and (see next page)

sledged into pieces successfully. When such rocks are to be blasted they should be drilled (blockholed) rather than mudcapped or undermined. Ledges of rock always should be broken up by blasting drilled holes. The limits of size of rock at which mudcapping becomes impracticable are explained on page 15.

Labor conditions are important. On some farms men are very scarce and wages are high. At other places there are periods when laborers are practically idle and can be put to disposing of stones, without much extra cost. In the former case it is wise to let explosives do all the work possible with no more drilling, sledging, handling and hauling than absolutely necessary. In the latter case the amount of explosives used should be kept down, and the idle men left to do the resulting extra work.

The time element is equally important. If nothing else demands the attention of the men on the farm, a slow method is all right, but when stones must be removed in a hurry, the quickest method probably is the cheapest in the end.

When the cost must be kept down as much as possible, and when easier and better methods are not available, burying and breaking by fire may be resorted to, provided there is labor available at little cost. Sledging, when practicable, is a cheap method if labor and time are not considered, provided good sledges are available. But it is slow, hard work. This applies to any way of disposing of rocks except blasting. If the conservation of energy as well as of time and men is desirable, the use of high explosives is the only method to consider.

Mudcapping is the easiest way to blast boulders in most instances, but takes the most explosive of the three blasting methods. It seldom should be attempted with boulders containing more than 15 cubic yards of stone unless they are thin slabs, and is expensive with trap rock or other very hard and tough material. Rocks should be flat rather than round, or at least should have a flat side on which the charge can be placed.



mudcapped a few days later with five sticks with the result shown in the second picture. Note that the entire rock has been reduced to small fragments requiring no further handling.

Undermining or "snakeholing" has practically the same effect as mudcapping, though it requires less explosives and, usually, a little more work. Blockholing, though effective and economical, requires time and tools to drill the holes.

Mudcapping and undermining are pre-eminently the methods to use where there are only a few boulders to dispose of, since one man can do in an hour by these methods what it would take much longer to do by any other method. Stones that are deeply imbedded should be undermined blasted lightly to roll them out, or at least to loosen them, before they are mudcapped. Some very large stones should be both undermined and mudcapped, with two or more charges fired simultaneously with an electric blasting machine.

Other combinations of methods will suggest themselves to a resourceful blaster.

Study the rock. If it is imbedded, roll it out by undermine blasting as above directed, and examine it on all sides. Usually you will find that an undermined or mudcap blast, unless the charge of explosive has been small, will break up the boulder and make blockholing unnecessary.

Detailed Directions for Disposing of Boulders

Small boulders, weighing only 100 pounds or so, may be dug out and rolled into wagons on planks, or dragged off the field with chains. With **Digging Out** larger stones, hauling is slow business, and is likely to result in injury to men. The hard straining required to lift the rocks, added to the danger from the falling of heavy stones, makes what would seem to be one of the simplest and safest of jobs an exceedingly hazardous one.

A practicable method of disposing of rocks is to break **Sledging Rocks** them up with sledges. Use heavy sledges—the heavier the better. The tough rocks are almost impossible to break in this way. It is impractical to sledge up large rocks of any kind.

Pay particular attention to the direction of the grain and the lines of cleavage. A blow right at a vital point often will break a rock in two when you could hammer away an hour at another part without much effect.

When you sledge rock, there is much danger from flying bits of stone, and it is a good plan to wear gloves. Tie your coat sleeves over the gloves or the gloves over the sleeves, turn your collar up, wear a cap which pulls down over the ears, and wear goggles. If you have no goggles, be careful to shut your eyes when striking the rock.

One way is to dig a pit alongside the stone, and tip it over. This is suitable for stones that can be pried over. Large stones must **Burying Rocks** be undermined and let sink down slowly. Let each end down separately. Extreme care must be used in this operation to prevent the rock from rolling on the man who digs. Burying heavy stones is a dangerous operation, and has crippled and killed many a man.

Burying rocks is open to the objection that at some time the work may have to be done over again, on account of not getting the top low enough. Frost, erosion, and other forces gradually have the effect of bringing the stones to the surface. If the rock is large, it will interfere seriously with the growth of anything planted over the spot. Buried stones are beyond your reach if needed for building purposes.

Dig a trench round the stone to be broken, as deep as the stone goes, or somewhat deeper. Gather a cord or two of wood to start with. Have plenty of large pieces—logs and the like. Build your fire, and see that it gets intensely hot. After it burns four or five hours, and the stone is thoroughly heated all through, suddenly draw away the fire and **Fire Breaking** throw on several buckets of cold water. It will snap and crack. Pieces will shell off the surface. Rake these away and renew the fire for another several hours, and repeat the water application. Gradually you will be able to wear the rock down and crack it entirely through. After two or three of such burnings you will be able to pry open the cracks that are formed and sledge up the remaining large pieces.

Be careful to keep out of the way of flying fragments when you throw on the water. Stones also often break with a loud crack when the fire gets very hot. See that none of the pieces strike you. In addition to their force, they will burn like melted iron, for they are almost red hot. One small piece in your eye may destroy the sight.

The easiest way of breaking stones is to do it with high explosives. **Blasting** The directions for this work are given in full detail, with careful attention to mudcapping, blockholing and undermining or “snakeholing,” and to combinations of these. In order to do the matter justice it is placed in a separate chapter.

Blasting Boulders and Ledges

All of the methods described in the preceding chapter are more or less useful, but in actual practice the disposal of boulders or ledges nearly always will be impractical unless you use explosives.

Mudcapping Rock

Briefly, mudcapping rocks consists in placing the explosive in a neat pile on a face of the rock, covering it with about 6 inches of stiff wet clay, and exploding it. When done right, the force of the explosion breaks the rock.

It is the enormous speed of the gases which accounts for the success of such a blast—the time element. Mudcap blasting is made possible by the intensely fast shattering action of some of the modern high explosives. It cannot be done satisfactorily with black powder nor with the slower kinds of high explosives.

Owing to the resistance of the air and the inertia of the material in the mudcap, the gases strike the rock like an enormous sledgehammer swung at a rate faster than the eye could follow. Such a blow, if in proportion to the size and strength of the stone, is sure to shatter it.

Of the three distinct methods of blasting, mudcapping is
Description the best one to use when the boulders to be broken are flat and brittle and smaller than 5 or 6 feet across.

Probably the most economical mudcapping per cubic yard of rock is in blasting sandstone boulders having flat sides, and containing 4 to 6 cubic yards. Some sandstone is brittle, yet hard to drill, therefore should be broken by mudcapping. Shale, slate, conglomerate and other such rocks break very successfully under mudcap blasts. Mudcapping is less satisfactory, owing to greater quantity of explosives required, when very hard and tough rocks such as trap, etc., are to be broken. In fact, mudcap blasting had better not be attempted on hard, tough rocks that are more than 3 feet in diameter unless no drills are to be had, and the stone must be removed immediately.

If the stone lies free on the surface, it is ready for the placing of the explosive. If it is buried in the ground more than a foot, it is a good plan to dig or blast away the dirt before attempting the mudcap blast. One way to do

this is to dig a trench round the stone, to within a
Preparing the Rock few inches of its bottom. Another way is to place one or more small charges down alongside the stone and to loosen up the dirt or throw it away from the sides, but in such a way as to leave the ground firm and undisturbed underneath. A third, and probably the best way where the stone is almost buried, is to explode a slightly larger charge down under one side of the stone to roll it out of its bed, and onto the surface of the ground. Then it is ready for mudcapping.

In determining the best point at which to place the explosive, consideration of the principles of rock structure, as outlined on pages 7 and 9, should be the basis. Study the make-up of the rock and de-

Locating the Place for the Charge termine the directions in which it will split the easiest. Look for and work for the hair-thin but far reaching seams. Clean the dirt or dust from likely-looking places. The joint lines most of the time will be hardly visible, yet they are important if the most complete and economical breaking is to be secured.

Some workers say that they put the explosive where they would hit the stone with a sledge if it would be possible to break it with one blow. The big

thing is to get the explosive at a vulnerable point on the rock, whether this is top or sides. It may be necessary to support the explosive and its covering of mud with a banking of dirt, or with props from the ground, if the charge has to be located down along the side.

It is better to place the explosive in a depression or hollow on the stone, or at least on a flat face, than on a round or bulging surface. A round face acts to some degree as an arch, and resists the blow of the explosive much more than a flat face. A depression gives the explosive some confinement that enables it to do better work.

In placing the explosive it sometimes is well to deepen crevices or depressions with a drill or cold chisel, in this way making what might be called a semi-mudcap out of the blast. Such a blast is more efficient than when the explosive is placed on a flat or rounding surface. If it is desired to break the boulder or rock into pieces of certain shapes and sizes, make channels across the face with a chisel or mason's hammer and place the explosive in these channels. The process is like breaking ice by chopping channels across it. This treatment gives rough dimension pieces, but it may increase cost.

The charge of explosive ordinarily should be placed in a low cone at the point selected on the rock. If less than four sticks are to be used, it is well to take all the explosive, except $\frac{1}{2}$ stick for priming, out of the paper wrapping and press it into place. If the charge is large, one or

Putting the Charge in Place more of the sticks can be left intact and bedded in loose explosive. Sometimes the sticks bed-in better when cut in two. The explosive should not cover much area on the stone, since widely spread charges tend to distribute their force and have lower breaking ability. Sometimes it is a good plan to place the explosive in a



How a mudcap charge is pressed down on a flat side of a boulder, with fuse projecting from the mud, and how a boulder is broken up. This charge was placed properly and was of the right amount. Note that none of the pieces were thrown far, though the stone is well broken up.

long, narrow mass—if there is a long depression, or crack, or the rock is much longer than it is broad. Thin edges of the mass should be pressed in and made steep and square.

Before all of the charge is in place, put in the cap with fuse or the electric blasting cap. See pages 34 and 41. The best way is to prime a part of a stick of explosive in the usual way and bed this in the loose explosives. If you decide to do this, stand the primed powder on end, with fuse or wires projecting from the top, and the closed end of cap pointing toward the center of the whole charge and then press the rest of the loose explosive about it.

If a primer of this kind is not used, the cap must be inserted directly in the charge. To do this punch a hole a little larger round than the cap about one-third of the way down in the top of the charge. The cap should be in the upper third of the charge. To place the cap deep in the mass might lower the efficiency of the blast.

Use the handle of the cap crimper or a blunt-pointed stick for punching the hole, as directed on page 38, and see that the cap is pushed to the bottom of the hole and that the explosive is pressed closely around it.

The covering of mud should be put over the charge carefully. Be sure that the cap is not pulled out of the explosives during the covering operation, or later.

The mud cap should be, preferably, of stiff wet clay. If clay cannot be got conveniently, use the heaviest earth you can find. Sand is the least satisfactory material, but can be used if made thoroughly wet. In any case, the mud-cap must be MUD and not dust.

At least 6 inches of mud cover should be placed over the explosive. This means 6 inches of covering in all directions over all of the charge. If the charge is 6 inches broad, then the mudcap would cover at least 18 inches of the rock, with the charge centered under it. To make a mudcap when the surrounding ground is dry, it is a good plan to gather and mix the mud in an old dishpan or box. Then to apply it on the rock simply turn the pan or box over at the right place and press the mud down so that no possible air spaces remain between it and the explosive or the stone. Be careful that there are no stones in the mud covering. They fly like bullets when the charge is fired.

The amount of explosive to use depends on the size and shape of rock and on its toughness and hardness. Below is a table which will serve to guide the blaster. These figures should be high enough to cover tough stones. Less explosive may be used for rocks that are easier to break. Rocks smaller than one cubic yard require more explosive than their size-proportion.

*Approximate Number of Pounds of Explosives Required for
Mudcapping per Cubic Yard of Rock*

Sandstone, slate and similar soft or easily broken rock	1 lb.
Limestone and other intermediate rock	1 1/4 lbs.
Marble, trap, granite and similar hard tough rock	2 lbs.

While this table serves as a basis for calculating the amount of explosive required to break boulders, it is only approximate, as the weight of the charge does not continue to increase according to the number of cubic yards in the boulder. Some blasters may prefer the following table, which gives the approximate number of sticks required for each diameter of stone.

Number of $1\frac{1}{4}$ x 8 Inch Sticks of Explosive Required for Mudcapping Boulders of Different Sizes

Sandstone slate and similar soft, more easily broken rock				Limestone and other intermediate rock	Marble, granite, trap and hard, tough rock
$1\frac{1}{2}$ ft. greatest dia.	$1\frac{1}{4}$ sticks			$1\frac{1}{2}$ sticks	$2\frac{1}{2}$ sticks
2 " " "	$1\frac{1}{2}$ "			2 "	3 "
$2\frac{1}{2}$ " " "	$1\frac{3}{4}$ "			$2\frac{1}{2}$ "	$3\frac{1}{2}$ "
3 " " "	2 "			$2\frac{1}{2}$ -3 "	4 "
4 " " "	4-5 "			5-7 "	
5 " " "	7-10 "				

Firing Charges Charges in mudcap blasting may be fired by either fuse and caps or by the electric method. The advantages of each method are discussed on pages 50 and 55. The electric method is the only one that can be used when more than one charge is to be fired at the same time.

The kind and grade of explosives best to use for mudcapping rocks is one having a very quick action of great shattering or disruptive power. The best explosive for this purpose is one of 40%, 50% or 60% strength. The straight nitroglycerin dynamites or powders are a little quicker in action than the "extra" or ammonium nitrate explosives, and for mudcapping should be the first choice. See page 44. But the ammonium nitrate dynamites or powders are equally powerful, when of equal percentage strength, and though they are slower in action, tending to break the rock into larger pieces than nitroglycerin explosives, their work is satisfactory for mudcapping.

When another explosive than those recommended above is on hand on account of some other use, it may be used for mudcapping with success, though its use may be more expensive. Almost any dynamite or high explosive powder, for farm, mine or quarry work, may be used in an emergency. Even the 20% high explosives that are best for soil blasting can be made to break rocks in this way, though their performance will not be very satisfactory. When these lower percentage explosives are used, particularly if of the ammonium nitrate type, the quantity must be increased greatly. The use of such explosives will result in cracking the stones into a few large pieces rather than into many fragments. Whenever there is much mudcapping to do it will pay to get the proper explosive. In cold weather, use only the low freezing grades of these explosives.

The only tools necessary for mudcapping are a shovel, a pocket knife and cap crimper, though an old dishpan or similar receptable and a water pail often can be used to advantage.

Breaking average sandstone boulders by blasting by the *mudcap method* on some jobs has cost fifteen to twenty cents per cubic yard. Granite, limestone, marble and trap rock boulders have been broken for slightly more. Mudcapping costs per cubic yard of rock run up fast when the boulders are very large, say larger than 6 to 8 cubic yards each. Trap and other tough rocks are expensive to mudcap. The shape of the rocks has much to do with the cost and practicability of breaking them in this way.

The approximate cost of mudcapping can be computed on the basis of the amount of powder required as given in table on page 17. The time required to mudcap rocks is very little. When wet ground for the mudcap is at hand, a man can have a stone lying round in pieces within 10 or 15 minutes after he

gets on the ground. Many practiced blasters use no more than 5 minutes for each boulder.

Three feet of fuse burns about a minute and a half and under ordinary conditions is enough to permit the firer to reach a place of safety. If an electric blasting machine is used, the operator should stand at least 250 feet away, and should watch for and dodge any flying piece of rock coming in his direction. Avoid standing behind a shelter that may let stones through, as the branches of a tree. See page 55 for discussion of misfires.

A rock will often break better if it is jacked or pried from the ground and allowed to rest on small stones under the ends or corners. Sometimes odd shaped rocks, particularly if they are long, are broken better with two or more mudcap charges placed at different points and fired simultaneously by the electric method, than by one charge. Usually it will be best to locate such charges on opposite ends of the rock, though this rule is not good every time. Sometimes one may be a mudcap and the other a snakehole or undermine charge. Before proceeding with any mudcapping, read the chapter of this bulletin beginning on page 43, about the nature of explosives, detonation, tamping, freezing, thawing, etc.

The result to be expected from a successful mudcap blast is to break the stone into a great many pieces, none of them too large to handle. If a heavy blast is used on a small brittle stone, half or more of the stone may be almost powdered, and few or none of the pieces may be much larger than a man's fist.



Two pictures: How a proper undermine blast can be made to break a stone that is partly buried. Two charges of 10 per cent. ammonia explosive were used under this stone, and fired simultaneously, with the result shown.

Undermine or Snakehole Blasting

To break a stone by the undermine blast method, the charge of explosive is placed against the under side or bottom of the stone with the solid ground as its backing. Less explosive is required than with a mudcap,

Description since the confinement is better, owing to the earth backing and the weight of the stone.

This method is superior to mudcapping because less depends on the shape of the stone under the ground or the depth it is buried, which are always hard to determine with certainty.

Undermining or snakeholing works better when the stone to be broken has a flat side down, and with flat boulders rather than round ones.

To shatter a stone by this method, as by other methods, due attention must be given to the hardness, toughness and seams,
Locating the Holes as outlined on pages 17 and 19.

When a boulder is well buried the first thing to do is to probe about it with a sharp quarter-inch steel rod, to learn the shape of the under side and the condition of the ground. In any case, the charge of explosive should be placed as near as possible underneath the center of weight of the rock.

Holes for the explosive can be made with a crowbar and sledge or with a dirt auger. The crowbar likely will be the most serviceable. If the hole is not large enough to hold all the explosive required at the right
Making Holes point, you can make use of a scraper to enlarge the hole at the bottom. See page 31 for description. In blasting very large rocks, small tunnels can be shoveled out.

The practice of enlarging the bottom of the hole by "springing" with an inch or so of a stick of explosive, is seldom to be recommended in undermine blasts of stones, on account of possibly enlarging the cavity too much and forming cracks extending into the surrounding earth.

The explosive should be placed as nearly against the rock as possible. When the rock is undermined by digging, the explosive should be packed in a compact bulk, as in a mudcap charge. If you get the
Placing the Charge charge an inch or two away from the rock with dirt between, its breaking effect on the rock will be reduced. Read the directions for loading a hole, on page 28, and for placing a mudcap charge on a rock, page 16.

The stick of powder containing the blasting cap should be the last or next to the last to go in. The cap should not be against the rock,
Inserting Cap but if possible in the outside portion of the charge. The business end of the cap should be pointing directly toward the center of the charge.

The charge must be thoroughly and tightly tamped. If there is not good firm resistance all the way round it will blow the dirt out from under the rock without doing any stone breaking at all. It is a good plan sometimes to tamp the dirt the whole way round the stone before the charge is exploded. Never use a metal tamping rod in the hole or near the charge of explosive. It may strike sparks from the rock or from small pieces of stone, and cause a premature explosion.

Firing the charges may be done either by the cap and fuse method or with electric blasting caps and blasting machine. Each method has its advantages and adaptations to certain conditions as fully explained on pages 50
Firing and 55. How to prepare charges, including the fixing of the fuse and cap, inserting and tying them in the stick of explosive and other details, are told on pages 33 and 42.

The amount of explosive required to shatter rocks by the undermining method depends on the size, shape, toughness and hardness of the rock. The table here will serve as a guide. These figures
Amount of Explosive should be high enough for average tough rock, but it must be remembered that the amount of explosive required does not always change according to the size of the rock to be blasted.

*Approximate Number of Pounds of Explosives Required for Shattering Boulders
"Snakehole" by Undermine Blasting, per Cubic Yard of Rock*

Sandstone, slate and similar soft or more easily broken
rock..... $\frac{3}{4}$ lb.

Limestone and other intermediate rock..... 1 lb.

Marble, granite, trap and similar hard, tough rock.... $1\frac{1}{2}$ lbs.

Some blasters may prefer a table based on the diameter of the stones. Such a calculation can be used satisfactorily, but in this case, too, a great deal depends on the shape of the boulder.

*Approximate Number of $1\frac{1}{4}$ by 8 inch Sticks of Explosive Required to
Shatter Boulders of Different Sizes by Undermine Blast*

Sandstone		Limestone and other tough rocks	Marble, granite, trap and similar very hard, tough rock
$1\frac{1}{2}$ ft. greatest dia.	1 stick	$1\frac{1}{4}$ sticks	2 sticks
2 " " "	$1\frac{1}{4}$ "	$1\frac{1}{2}$ "	$2\frac{1}{2}$ "
$2\frac{1}{2}$ " " "	$1\frac{1}{2}$ "	$1\frac{1}{4}$ "	3 "
3 " " "	$1\frac{1}{4}$ "	2 "	$3\frac{1}{2}$ "
4 " " "	3-4 "	4-6 "	
5 " " "	6-7 "		

If larger sizes are to be broken, better calculate the amount of explosives required by the cubic yard basis. Your figures will be more accurate. When rocks are to be rolled out without shattering, comparatively small charges can be used. The following table will give an idea of the amount of explosive necessary.

*Approximate Quantity of Explosive
Required to Roll Out Buried
Boulders*

$1\frac{1}{2}$ ft. dia.	$\frac{1}{2}$ stick
$2\frac{1}{2}$ " " "	$\frac{3}{4}$ "
3 " " "	1 "
4 " " "	$1\frac{1}{2}$ "
5 " " "	2 "

Larger sizes than listed require proportionately increased charges.

The extent to which the boulder is buried and the nature of the ground also influence the amount of explosive required.

Probably the most economical explosive for breaking rock in this way is 30% to 50% strength dynamite or powder of either the nitroglycerin or ammonium nitrate class. On account of the better confinement secured in this method, stones can be broken more effectively and successfully with slower and less powerful explosives than by mudcapping. 20% to 40% strength

**Kind and Grade
of Explosive**



A striking illustration of the action of a proper undermine blast. The rock is lifted a few feet and cracked, but is not thrown far. Look closely and you can see the cracks where they had begun to form at the instant the picture was made.

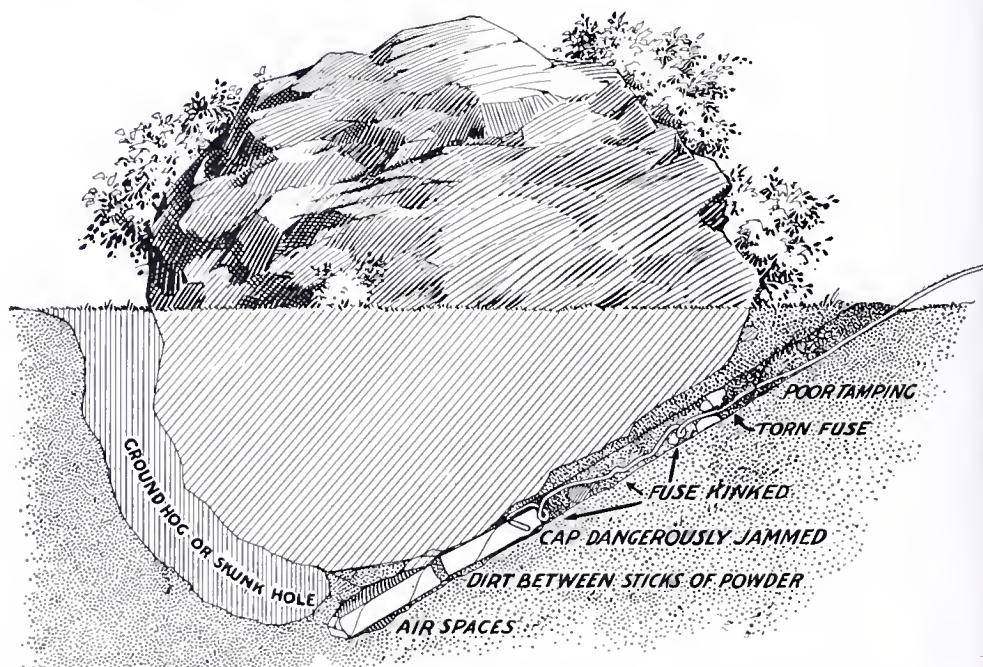
explosives often will prove satisfactory. Any standard strength of nitroglycerin, ammonium nitrate or gelatin dynamite will do the work.

To roll stones out without breaking them, the high percentage explosives can be used successfully, but they are not as well suited to the purpose as the slower ones, such as 20% ammonium nitrate dynamite or powder. If you are buying explosives for breaking rocks, however, buy those best suited to the actual breaking, and do the rolling out of the stones with the same explosive.

The tools needed in snakehole or undermine blasting of boulders are the testing rod or probe already mentioned, a shovel for handling dirt, a crowbar or dirt auger, a wood tamping rod $1\frac{1}{4}$ inches in diameter, and a cap crimper. Several other items in the tool list can be made use of to good advantage where there are many stones to undermine. One is a 3-inch fence post, to tamp the ground tight about the edges of the stone. Another is the scraper, for enlarging the bottom of an auger hole.

Undermine or "snakehole" blasting is a slightly cheaper method than mudcapping when conditions are favorable. It is often found that the cost per cubic yard increases with stones smaller than one cubic yard, and is very much less with stones containing several cubic yards. Sandstone has cost ten to fifteen cents per cubic yard to break in this way, and the other kinds in proportion. This is one of the most serviceable and satisfactory methods of blasting boulders. The cost can be calculated by referring to table on page 21. Add labor cost to the total for explosives. Sandstone and other such easily broken material can be broken up cheaply, while marble and trap come higher. Although the cost of explosives is somewhat less than with the mudcap method, this is partly offset by the additional labor required in making the holes in the ground. Ordinarily a man can make a hole and place a charge under a stone in 15 to 20 minutes.

Combinations of snakeholing and mudcapping sometimes are effective with stones that lie on the surface of the ground or are imbedded only a little.



A combination of evils. Such loading could not result in breaking a boulder. Note the seven faults.

Suggestions To make use of the advantages of such a combination an electric blasting machine to produce simultaneous exploding is necessary. It is not wise to attempt the combination of top and under shots when a stone is buried deeply. Better roll it out first.

Two points of caution are desirable. Beware of misfires. See page 55. Remember that snakehole or undermine blasting may throw pieces of rock with considerable force and range, but the danger can be reduced

Cautions to a minimum if proper precautions are taken to see that every person and animal is out of range of flying rock and fragments. It is not unusual in snakehole or undermine blasting to see pieces of stone thrown more than 100 yards.

Blockholing

This method of breaking rock with explosives consists in drilling a hole into the boulder, putting the explosive at the bottom, tamping tightly, and firing in the usual way. It is remarkable how small a charge of explosive will break a big boulder, even of the hardest and toughest kind, when placed in this way. One stick of explosive in a drill hole 18 or 20 inches deep in a rock will do more damage than several sticks on the surface.

Description The blockhole method of blasting is the best way of breaking large, tough boulders that are not too hard to drill and which do not break well from a surface blast.

Drilling and blasting in a similar way is nearly always the only practicable method of blasting ledge rock.

The nature of the rock has a good deal to do with the point at which it is best to place the explosive. Ordinarily it will be found that the charge should

Character of Rock and Placing of Explosives

be located somewhere near the center of the boulder, though different kinds of rock require different depths of holes. A brittle rock which does not split well and a tough rock such as trap, must be drilled deep in order to break it right, while a shallow hole will give satisfactory results in a rock which is easy to split, or which crumbles apart like slate.

A rule that may be applied to all rock is that the deeper the drill-hole, down to $\frac{1}{2}$ or $\frac{3}{5}$ the way through the rock, the less explosive will be required, and the greater will be the execution of the blast. In boulders that are very hard, and so big that they require a large charge, it once in a while pays to drill a very small hole, and then spring this hole at the bottom by exploding at that point a small charge of explosive, using no tamping. Such a practice will be needed rarely in boulder blasting, though it is often useful in blasting out ledges.

Drilling Facts Holes may be drilled by one man alone, or by two or more men. One-man drilling usually is the cheapest when holes are made by hand. The drilling can be done with ordinary hand hammer drills, with churn drills (finishing deep holes), or with machine drills.

A hand drill is just a straight piece of drill steel, which is medium hard and very tough, with one end shaped into a proper cutting bit. This bit is $\frac{1}{3}$ to $\frac{1}{2}$ or more wider than the shank of the drill, with the

Hammer Drills cutting edge somewhat rounded up to the corners and sharpened in the form of a "v," the angle of which should be long and thin or short and thick, according to the kind of rock to be drilled. In soft rock use a long thin cutting edge; in hard rock a short, thick edge.

You can buy drills of different lengths and diameters from mine supply houses or hardware dealers anywhere. Or you can buy the steel from hardware stores and make them. Drill steel comes in $\frac{5}{8}$ -inch, $\frac{7}{8}$ -inch and other diameters, in bars up to 20 feet long. If you plan to make your own drills, be sure to have on hand a good length of it, for even if you have only a dozen boulders to blast you will need several drills as they require sharpening frequently.

If one man is to do the drilling, the hand hammer should weigh 3 or 4 pounds; if two men, 8-pound sledges are about right. All hammers should, of course, be flat faced. The drill should be turned about $\frac{1}{8}$ of a revolution at each stroke of the hammer so as to keep the hole round. The more regularly this is done the nearer true the holes will be and the faster the bit will cut. The holes can be started with a short drill—say 8 or 10 inches long—easier than with a long drill.

The right diameter for a hole in a boulder usually will be about one inch. It is well to keep the hole as small as possible, for it takes a good deal longer to drill a big hole than a small one. For instance, it takes **Size of Holes** about four times as long to drill a 2-inch hole as one an inch in diameter. If the 1-inch hole will contain enough explosive it should be the size selected. But it must be remembered that as the hole goes down, the ears of the drill bit will wear off and the hole will grow smaller, so that in hard rock it is well to start a hole that is to go deeper than a foot or so, with a drill $\frac{1}{4}$ inch larger than is wanted at the bottom. In boulders containing more than 6 or 8 cubic yards of material it is best to drill inch or inch and a quarter holes.

The holes should be kept wet by pouring in water as the drill goes down. In this condition, the drill cuts much faster than in dry holes. It is necessary to keep the holes clean. The sledge, as the ground-up rock is called when mixed with water, can be taken out with a scraper which is shaped somewhat like a very small garden hoe, or with a spoon rod, which is a small wood rod with a disc of tin on each end. The discs should be of different sizes, and at



Pressing in the tamping after a charge of explosive has been seated in the bottom of a blockhole

one point they should be cut to the center and one of the cut edges bent down, so that when the rod is revolved in the bottom of the hole the edge will scoop up some of the sludge.

Another good way of cleaning out holes is to use a spiral hook, or drag twist, like an old-fashioned rifle cleaner. Rags or hay can be used on this to wipe the hole. A hickory or willow stick with the end split into many small pieces, or broomed, is also a good thing for getting dirt out. When this is dipped in the sludge, the material sticks to it, and can be lifted out and knocked off against the outside of the stone.

A leather or rubber washer, or some old rags, should be fixed round the drill just above the level of the stone, to prevent the sludge and dust from flying up into the face of the driller. This is particularly necessary when churn drilling.

A churn drill is a piece of drill steel from 5 to 6 feet long, often having bits at both ends. It is used without a hammer—a man raises and drops it into the hole. Holes cannot well be started with it. It will cut holes faster than a hammer drill under favorable conditions, but owing to the way it is worked its use should not be attempted in holes less than 6 or 8 inches deep. For deep holes and in soft rock it certainly should be considered. A good churn drill for 1-inch holes should weigh about 10 pounds.

Bits should be kept sharp, for dull drills do only a fraction of the work they should. To sharpen bits costs about five cents each. It may be done in a blacksmith shop or, in emergencies, with a file or on an emery-wheel or grindstone. They should be made as sharp and hard as they can be used in the rock to be drilled without either dulling too fast or chipping. The angle of bevel that is best generally will be about 90 degrees for hard rock and 45 to 60 degrees for soft rock. Your blacksmith will give you the proper kind of bevel if you give him the necessary information. Good drill steel is not tool steel.

Before attempting to sharpen a drill the shape of a new bit should be observed. Heat the drills to cherry red, and do not hold them long at that temperature. Work to get them hot without delay, then take them out of the fire promptly for dressing.

The bit should be hammered to shape on the anvil, with the shank of the drill held so that it has 1 foot rise to 2 feet of length. You likely can use a file to advantage to help shape the edge, while the steel is hot. When the bit is shaped, it is ready to be put back into the fire and reheated for tempering.

The tempering should be started when the steel is at a temperature of 430 degrees F. You can tell the temperature by the shade of the surface or color film that forms on the surface as the steel is being heated.

When the bit has been heated slowly until the surface has nearly a cherry red shade, take it from the fire and hold it in the air till it gets a very pale yellow. Rub it on a stone to remove the scales so the color can be seen unmistakably. If it seems to take too long to reach this color in the air, plunge it into the water and out again at once to start the cooling. Then watch the colors by standing in a dark corner. They should advance parallel to the edge. If they don't, hold the hot corner or side in the water an instant to even up the entire bit. As soon as the very pale yellow color is noticed, stick the bit into cool water and leave it there, stirring it about till most of the heat has left the steel.

Temperatures of the steel that are indicated by the colors are as follows:

Very pale yellow.....	430	degrees F.
Straw color.....	470	" "
Brown.....	490	" "
Purple.....	530	" "
Full Blue.....	560	" "
Dark Blue.....	600	" "
Cherry Red.....	900	" "



How a proper blockhole blast will shatter a boulder into pieces of all sizes. Note how completely the stone is broken throughout its entire volume and not just at one side or corner.

The time in which two men with hand drills can make holes in rock can be told best by stating the number of minutes it takes per inch of hole in different kinds of rock. For beginners, when two men are drilling holes an inch in diameter in rock such as sandstone, about $2\frac{1}{2}$ to 3 minutes per inch in depth is required; in limestone 3 to $3\frac{1}{2}$ minutes; in granite 4 minutes; in mica schist 5 minutes; in marble and trap rock 6 to 8 minutes. Single hand drilling (one man) proceeds about two thirds as fast, except that in soft rock the rate is upwards of three-fourths as fast and in very hard rock only half as fast. These figures change greatly according to the experience of the workers and the condition of the sandstone, limestone, granite, schist, marble or trap rock that is drilled.

The cost, including sharpening of drills, will run about 25 cents a foot in the easily drilled rock up to 70 cents in the very hard, tough rock.

Machine drilling is very much faster than hand drilling, and much cheaper where there is enough drilling to do to justify the purchase of an outfit. Since there are many owners of large acreage which requires clearing, also many contractors in stump and stone removing who will use this handbook, some of the data about machine drilling will be useful.

In clear rock, or rock not checked, machine drilling is 5 to 15 times as fast as hand drilling. In some sandstone it is possible to go down at the rate of a foot in 5 minutes (instead of an inch or two as in hand drilling); and in trap rock at the rate of a foot in 10 or 12 minutes. In limestone the rate is even faster than in some blue sandstone, there being records of instances where a foot has been drilled in 3 minutes. Hard granite and flinty rock often drills at the rate of a foot in about 7 minutes.

Blockhole blasting is more economical than undermining, the cost depending partly on how difficult the rock is to drill. Large rocks of a hard and tough nature, cost pretty regularly around 16 to 17 cents per cubic yard of stone to break by this method. Blockholing requires a smaller amount of explosive and larger amount of labor and time than mudcapping or "snakeholing."

The cost of machine drilling usually is much lower than of hand drilling—often it is about one-fourth or one-third, of course not including depreciation or interest on the cost of the outfit. This is much or little per foot of hole drilled, according to how steadily the outfit is used. It may amount to only a fraction of a cent, or it may run the total cost up higher than that of hand drilling. There are some power machines which it is claimed will drill at a cost of 6 cents per foot. Others drill at a cost of 10 cents per foot, but 10 cents is high.



How a boulder can be broken into pieces small enough to handle easily without shattering it into fragments, with proper charges of 20 per cent. ammonia explosive placed in a blockhole, or by 40 per cent. explosive used as a mudcap. This stone shows by its breaking how joint and bed lines run.

There are two types of machine drills operated by steam or compressed air—the small jack hammer and the large tripod drill.

The jack hammer drill is the best type of machine for use on boulders. Jack drills are portable and easily handled. Tripod drills are heavy.

The tools needed in blockhole blasting, aside from drills and hammers, are a pocket knife for cutting fuse or scraping wires, a cap crimper and a wood rod for tamping. Crowbars are often useful.

The kinds and grades of explosives that can be used for blockhole blasting are many. In fact, rock can be broken by this method with almost any blasting explosive. But certain facts should be understood by blasters. One is

Kinds and Grades of Explosives that the use of a high strength quick-acting explosive, such as 50% or 60% powder or dynamite will shatter rock into small pieces, while the use of slower explosives such as 20% strength will crack and split it into larger pieces. Ammonium nitrate dynamites or powders are considered somewhat superior to nitroglycerin explosives for this purpose. For the ordinary breaking of boulders into pieces small enough to handle easily, there is nothing better than 20% to 40% ammonium nitrate powder or dynamite.

In blasting in quarries, 5 tons of rock often are brought down per one pound of explosive. It is difficult to maintain this ratio in the field, unless it be with very large rocks, or **Amount of Explosive Required** ledges with an open or free face. Small boulders often require more explosives per cubic yard than large ones. The shape of the boulder is also an important point, so the following tables can only be considered as approximate.

*Approximate Number of Pounds of Explosives Required
to Break Boulders by the Blockhole Method,
per Cubic Yard of Rock*

Sandstone and other more easily broken rock	$\frac{1}{4}$ lb.
Limestone and other medium rock	$\frac{3}{8}$ lb.
Marble, trap and similar hard, tough rock	$\frac{1}{2}$ lb.

Figuring on the basis of the diameter of the stones and the number of sticks of explosives required, the tabulation is:

*Approximate Number of Sticks of Explosive Required to
Break Boulders of Different Diameters*

Sandstone, Slate and similar easily broken rock	Limestone and other medium rock	Marble, Granite, Trap, and similar hard, tough rocks
$1\frac{1}{2}$ ft. dia. $\frac{1}{4}$ stick	$\frac{1}{4}$ - $\frac{3}{8}$ stick	$\frac{1}{2}$ stick
2 " " $\frac{3}{8}$ "	$\frac{1}{2}$ "	$\frac{1}{4}$ "
$2\frac{1}{2}$ " " $\frac{1}{2}$ "	$\frac{1}{2}$ "	1 "
3 " " $\frac{1}{2}$ "	$\frac{1}{4}$ "	1 "
4 " " 1 "	$1\frac{1}{4}$ "	2 "
5 " " $1\frac{1}{2}$ "	2 "	3 "
7 " " 6 "	8 "	10 "

Often from experience, an observant man will learn just how much explosive is required to crack a stone and lay it apart without excessive throwing of pieces, danger and waste of explosives.

All water should be wiped out of the holes. If the holes are smaller than the sticks of explosive the paper wrapping of the sticks will have to be removed and the explosive pressed into the hole so that there are **Loading Charges** no air spaces. The cap should be placed in the charge near the top. Tamping of damp or wet clay or other earth should be placed solidly over the explosive to the mouth of the hole. Results of the blast with the smallest charges will be poor unless there is at least 6 or 7 inches over the powder.



An undermine blast that was too heavy was used here to break a very hard, tough boulder. As a consequence the rock is broken only into large pieces and these are thrown long distances. A better way would have been to have used a very heavy mudcap blast on top of the rock, or, still better, a proper blockhole blast.

The firing of blockhole charges may be done either with fuse and cap or by the electric method. If more than one charge is to be fired, the electric method will enable you to put them all off at once. Electric firing is of much advantage in blasting out ledges, and also in firing the very small charges sometimes used to break stone to certain dimensions.

Sometimes what may be called a "semi-mudcap" blast can be used in very hard stone, or in stones that are difficult to drill. Drill a hole into the stone for 3 to 8 inches, fill with explosive, let the rest of the charge of explosive pile up on top of the rock as you would a mudcap charge, in a low cone with steep edges. Cover this with 6 inches or more of wet clay.

Boulders that are buried may be thrown out of the ground before they are blockhole blasted. When the earth is supporting them on all sides they may not break quite as well. Digging round them or raising them off the ground with a jack or pry, and letting them rest on small stones placed under the ends or corners, helps to break them up better.

Blasting in drilled holes is practically the only method that is effective in breaking up ledges of rock, either underground or above the surface. Drill a line of holes along back of the edge or face of the ledge

Breaking Ledges above the surface. It is not necessary to dig or blast away the dirt from a ledge. The quantity of explosive required can be gauged by the table giving the amount to use per cubic yard of rock. Use half again as much explosive in a ledge blast as in a boulder. Measure the distance from the open side or face of the ledge back to the drill holes, and compute the number of cubic yards that should be broken off.

Ordinarily on farms or in roads it is desirable to break up ledges to a depth of about 2 feet below the surface. To do this the holes should be put down slightly more than 2 feet and should be located 2 or 3 feet back from the face of the ledge. To break ledges deeper, drill deeper holes farther back from the

face and charge heavier. The deeper holes can also be farther apart. Two-foot holes usually can be 5 feet apart in soft, brittle shale and slate, 4 feet apart in limestone, and 3 feet apart in harder material. The spacing between the holes should be about the same as their distance back from the face. The details of charging holes, drilling, tamping, firing, etc., that have been giving for boulder blasting apply equally to ledge blasting.

Blockhole blasting is perhaps the most efficient method of breaking rock that is known, and from it you can expect perfect results. If you use a proper charge of a quick explosive, the rock will be shattered into small pieces. If you use a slow explosive, the rock will be broken into larger pieces. In any case, the use of the charges recommended here will result in the satisfactory breaking up of any rocks you may have to deal with.



How boulders are shattered into fine pieces by heavy mudcap charges of 60 per cent. nitroglycerin explosive. Note the amount of stone that is so small it will not need to be hauled away.

General Considerations

The information on boulder blasting, and particularly on the breaking of ledges of rock, applies to quarrying limestone or road material, gravel, etc.

In quarrying, it is better to drill larger holes than one inch. Proper loading in inch and a half holes, drilled to depths of 6 or 8 feet, and 5 or 6 feet back from the edge of the quarry ledge will loosen large quantities of rock.

It does not pay to dig hard-set gravel or sand by hand, for in such material the holes are easy to drill, and comparatively small charges of explosive will loosen great quantities. For quarrying use 40% ammonium nitrate explosive unless the rock is wanted in large pieces, when 20% ammonium nitrate grades will be better. For the semi-rock, hard gravel, etc., use 20% explosive, the granular powder known on the market as R.R.P., or if the work is dry, black blasting powder. Medium tough rock can be quarried at a cost of 50 cents per cubic yard, including the cost of drilling but not of crushing, screening and hauling away the stone.

Emphasis should be placed on the possibility of using explosives as a labor substitute. To illustrate, take the disposal of a 4-foot sandstone boulder. To drill this with an inch hole 32 inches deep would require about $1\frac{1}{2}$ hours, or slightly less, for two men. But one man can smash the same boulder within

Explosives as a Labor Substitute 10 minutes by placing a proper mudcap blast. In the first case the breaking of the boulder is achieved with greatest economy in total outlay, but in the latter case it is broken by one man, and broken without interfering seriously with other work. On many farms there is so much to do and men are so scarce that to take the $1\frac{1}{2}$ hours for the boulder's removal is out of the question, and the boulder remains in the field—unless it can be broken up with little labor and loss of time.

When a boulder that is nearly all buried is rolled out and blasted, there likely will be room in the hole for many of the large pieces, deep enough to put them all below the plow line, but it is not well to bury

Disposal of Pieces pieces larger than 6 inches in diameter, as the broken rock will be valuable for building purposes, for road making, lining ditches, etc., and should be kept in the stone pile until needed.

It costs about 35 cents a cubic yard to haul pieces of stone away, figuring on the average haul. Solid rock of average density weighs about 2 tons to the cubic yard and loose material as it falls weighs about $1\frac{1}{3}$ tons to the cubic yard. It is better to put a stone rack on a wagon if a wagon is used.

Hauling Such a rack can be made of 2 or 3 inch plank. To get heavy pieces of stone on the wagon, use planks to skid or roll them up. If the pieces are very heavy, use a "stoneboat" instead of a wagon. It is better for short hauls because it saves so much lifting. An average load of stone is about a ton and a half, and two men will handle this in about half an hour, including loading and unloading.

The holes from which boulders have been taken should be filled level, to avoid a low place in which water will gather during wet weather. To fill the depressions, a horse drag scoop such as is used in excavating

Filling Holes dirt is a useful thing. If this is not available, a good thing to use is an ordinary road drag, or a split log. By standing on the drag or log it can be made to gather a lot of ground, and the dumping can be done by taking off or shifting your weight.

In addition to various tools described under the separate headings on methods, blasters of boulders will find a heavy crowbar and an iron wedge to be useful at times for prying apart pieces of rock. Some blasts will be found



Steel bar for making holes.

Soil auger—note long point.



Tools and Appliances not quite heavy enough to throw the stones apart, though they will crack the rocks through and through. These stones can be reduced with a sledge, but a little prying will accomplish more than a whole lot of hard hammering. If the bar cannot be forced into the crack use the wedge and sledge it in. Be careful that the wedge does not strike solid rock at a bed or joint line running at right angles. The wedge should be a slim piece of tough steel, 6 inches long and an inch or two thick at the base.

The best tamping material is damp clay. Tamp the hole full, while working in the tamping with the stick in one hand, hold the fuse or the electric wires out of the way with the other hand. It is easy to damage fuse and wires by breaking the insulating with a pebble, or with the edge of the tamping rod. It is also easy to pull the cap out of the primer charge unless the fuse or wires are held firmly against the rock. Many misfires are due to carelessness at this point.

In lighting a fuse, stick the flaring head of a burning match right against the powder in the end. See page 41. This will work in any wind. The fuse always gives a pronounced spit as soon as it is lighted. Do not leave before the sparks and smoke begin to spit out regularly.

It may be safe to stand 100 to 150 yards away from a blast that is not overloaded, but this is a matter which each blaster will have to decide for himself. So much depends on the proportion of the charge to the boulder, its location, and as to whether the stone is solid. The right charge will not throw stone far, but a charge that is too heavy, or in the wrong place, will throw large pieces for long distances. In fact, this is one of the ways in which you can tell whether or not you are using too much explosive. In any case, to be safe, keep an eye on the blast and dodge any flying fragments coming your way.

Use every care to keep everybody beyond the range of danger. The man who fires the charge should keep his eyes open for stones coming down several seconds after the blast and at distances 100 yards or farther away.

They are dangerous. See page 55 for discussion of Watch Misfires their cause and remedy.



How a large granite sandstone or limestone boulder can be shattered with a mudcap blast. At the point next the explosive the stone is broken into small fragments, but at the other side it is left in large pieces, though it is well cracked in every direction.

Preparing Charges of Explosives for Firing

A charge of explosives for the purposes of these directions is considered to be all the explosives needed for a single hole with cap and fuse or electric blasting cap properly inserted in the stick of dynamite or powder (see pages 36 to 37) and tamped in the hole, ready to fire. The preparation of charges is practically the same for all sorts of farm blasting. The slight variations advisable to suit different kinds of work are not enough to call for separate treatment, since the principles are all the same.

All who use and buy explosives should read the next chapter, beginning on page 43, on the nature and actions of explosives. It is only the man who understands all the facts mentioned there who will be able to load and blast with greatest ease, speed and results.

Scope of This Chapter

It is important for everyone who blasts to understand why he does things, as well as how to do them. For that reason the following discussion of the preparation of charges is made full and complete, with due attention to all the important factors involved. Details of any particular part of the operation can be found quickly by referring to the heading desired, as given in the index.

Readers who may not desire a full discussion are referred to the following brief outline of the process.

Be careful that explosives, cap and fuse are in perfect condition. Cut a length of fuse sufficient for the hole to be loaded, making the cut clean, without dragging ends, at a slight slant of, say, 30 to 45 degrees from right angle.

Pick a cap from the little tin cap box, carefully, with your fingers, and slide it gently on the end of the fuse. With a proper cap crimper fasten the cap securely to the fuse, making the crimp close to the open end of cap. Avoid twisting or punching the end of fuse against the bottom of cap as well as drawing it away from the bottom. For wet work waterproof the joint of cap and fuse with tallow, soap or other material. Do not use thin grease or oil.

Next punch a hole at a long slant in the side of the stick to be primed. Better use a wooden punch for the purpose. The handle of the cap crimper may be used.

Insert the cap in the hole made as described, tie the fuse in place, and, for wet work, waterproof all openings in the stick. You then are ready to load.

Provide space enough in the hole at the proper point to hold the required amount of explosives in a bulk that is not too long. Be sure before you start to press in the sticks to the bottom of the hole (see page 28) that there is enough clearance to permit their easy and certain entrance. Tamp fully and firmly up to the top of the hole.

The charge is now ready to fire, which may be done by pressing the burning or flaring head of a freshly scratched match against the powder in the split end of the fuse.

Carrying Explosives and Supplies

The place to keep the explosives is in the magazine or storage place, and not with you in the field. Carry with you in warm weather only enough for the job or the day, or in cold weather only as much as can be kept warm and in condition for firing until you are through loading. Keep explosives separate from caps.

Protection of Explosives

A good way to carry the caps, fuse and small tools is in a basket. Put a piece of blanket in the bottom, to keep

out dampness when the basket is on the ground. Some blasters use an explosives box for the purpose, putting a wood handle or double wire bale on it. The tight wood box probably is a little better than the basket because it affords somewhat more complete protection to the contents.

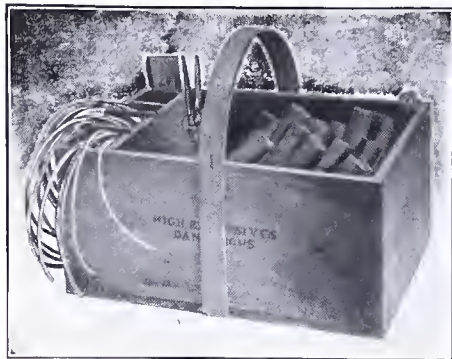
Whatever the method of carrying the explosives, it should be well protected. This consists in keeping the hot sun off it, keeping rain and fog off it, keeping it away from dampness of the ground, and keeping it safe from meddlesome people and animals.

Many blasters prepare charges before going to the field, but it is better practice to carry along the tools and materials, and to put them together or make the primers on the spot after all the holes are made in the ground or rock, and when everything is ready for the firing except to put the explosive in place.

These remarks are given as reminders. Full discussion of proper handling and storing of explosives can be found on pages 58 to 60 respectively.

Tools and Materials Required

The first step in preparation of charges is to assemble the following: as many sticks of explosive (or parts of stick, if charges are to be less than full sticks) as there are holes to be primed; an equal number of caps; a sufficient quantity of fuse; some string; a wood punch with an end the size of a cap for about 3 inches; a pair of cap crimpers; a pocket knife. If the holes are very damp or full of water you also will need some tallow or other waterproofing material. In certain cases a sharp hatchet or axe and a block of wood will be worth having. The purpose and use of these items will be made clear later.



A handy box for carrying supplies to field.

Putting Caps and Fuse Together (Making Primers)

Fuse is described as to sizes and properties on page 57 and caps on pages 56 and 57. Readers who are not familiar with them should turn to those pages at this point. Unroll the fuse and cut off a length that will be enough, since fuse burns about 2 feet in a minute (there are variations—see page 58).

Three feet will give you $1\frac{1}{2}$ minutes or a sufficient time to get beyond danger under ordinary conditions. The fuse, of course, must be long enough to reach out of the mouth of the hole when the charge is in place. Measure the depth of the hole before you cut the fuse.

Warm cold fuse before attempting to bend it. It may be taken into any warm room for the purpose but should be subjected to no heat greater than 110 degrees. If for any reason you have doubts about the condition of your fuse, cut off a foot or more and try it without any cap or explosive. If it will burn properly it is all right.

Be sure to get fresh ends both for the match and to put into the cap. If fuse has been cut for some time into lengths, it is well to cut off short pieces from the old ends in order to bring fresh powder right to the tips.

Cut the fuse off at a very slight angle or bevel—say 30 to 45 degrees, as shown in the diagram. This slant is for the purpose of giving a little space between the actual end of the powder and the explosive material in the bottom of the cap, to enable the spark

Cutting the Fuse to spit into material.

The only way to regulate the space is to cut the fuse as directed and let the long tip rest gently against the bottom of the cap. The spark has a better chance to ignite the explosive material in the cap when it spits from the end of the fuse than when it merely burns up to the end without any space to spit into.

The end of the fuse where cut off should be clean and free from dragging ends and threads. If it is not cut off clean, part of the covering may double over the end of the fuse in the cap and keep the spark away from the explosive, causing a misfire. Be careful to keep both ends of fuse off damp ground and out of puddles of water.

If the fuse has been mashed, or is too thick to go into the cap easily, do not peel off any of the covering. Reduce the diameter by squeezing it with the cap crimpers or by rolling it on a smooth surface under a knife blade or other smooth implement. Sometimes you can reduce it by rolling it between the thumb and finger.

The very best way to cut fuse is on a block of wood with a sharp knife. The blade can be pressed right through the fuse and will make a clean cut. Another good tool is a sharp axe, to be used on a block of wood. The method of cutting is of small importance, just so the actual cut is made smooth and even enough. If you do use other tools, have a knife with you to trim up ends that are not true. Be careful to avoid twisting, pinching or otherwise knocking the freshly cut end of the fuse about, for you may shake out the powder back far enough to cause a misfire. The powder should come out flush with end.

To get one cap out of the tin box in which they came, tilt the box up on edge till some of the caps slide forward, and then pick the cap up with your fingers. Don't attempt, on penalty of losing a hand, to take a cap out of a box by running a nail or a little stick or the fuse into it in the box. Be careful you do not drop a cap to the ground or floor.

The Cap Turn the cap upside down, to make sure there is no dirt in it, and gently slide it on the fuse till the end of the fuse just touches the bottom of the cap. Do not ram, press or twist the end against the bottom.

Hold the fuse with capped end up, to keep the cap from sliding off, and crimp the cap fast. This you do with the special plier-like tool called a cap crimper. The



"Crimp" or fasten caps to fuse with a regular crimping tool. This tool does the job far better than it can be done in any other way.

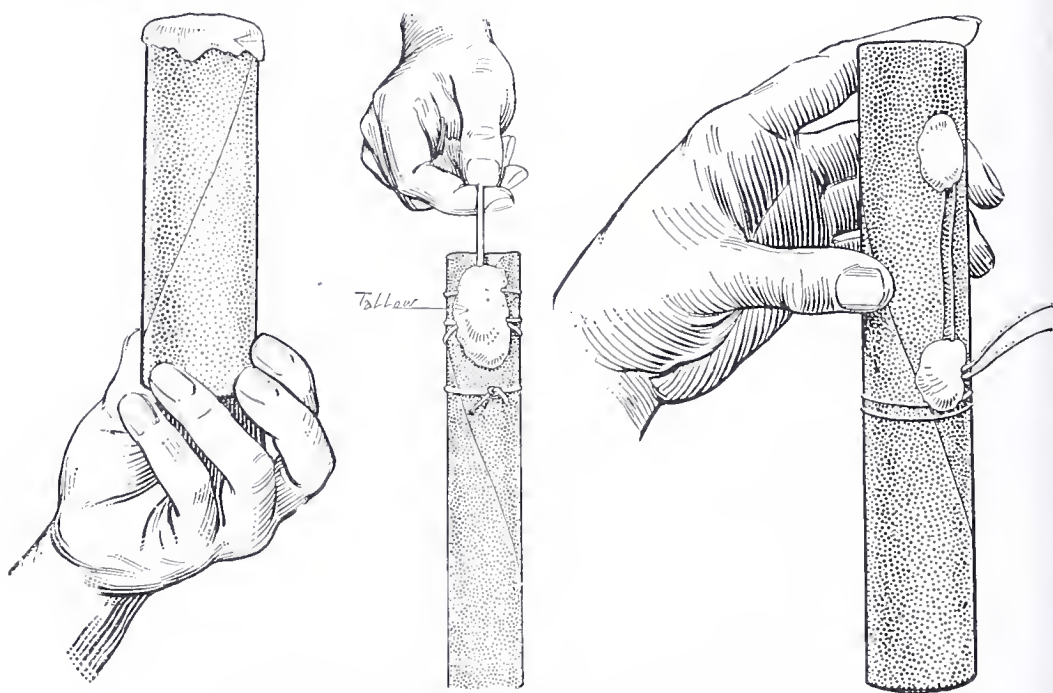
"crimp" is made by pinching the open end of the cap tight to the fuse. It

Crimping should be made within the last quarter inch of the open end of the cap. Never make it toward the closed end because you might disturb the explosive material in the bottom of the cap and cause it to explode.

Cap crimpers are supplied by

all makers of explosives. Order one or more when you buy your explosive. It is well to have an extra one about to use in case you lose one on extensive jobs.

This fastening of the fuse to the cap is one of the points in blasting where a great deal of abuse occurs. Blasters think they can take a chance with danger or with misfires, and attempt to crimp the caps some other way. Except in extreme emergency don't try to crimp a cap with anything except a regular crimping tool; but there are times when one may not have a crimper nor be in a position to wait till one can be purchased. There is a way out of this difficulty—which is to secure a makeshift crimp with something else than a crimper. It is possible to use a pair of pliers, or a small pair of pincers, and accomplish something that may hold the cap on the fuse. The best makeshift crimp is to take a fold of the cap up at one side of the mouth with a pair of close fitting, square-nosed pliers. Be careful while doing this that you do not grind the end of fuse against the bottom of cap, or pull the end back from the bottom. If the fuse should pull away from the bottom of cap a quarter inch, a misfire likely would result.



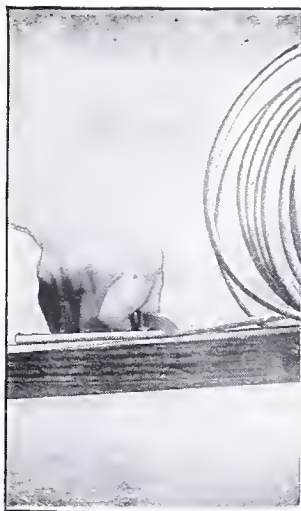
Waterproofed (tallowed) sticks ready for loading in wet holes.

When the charge is to be placed in a dry hole, waterproofing is not needed, but in a wet hole the connections between fuse and cap must be made water-tight with tallow or soap. Do not use grease, because it may unite with the tar in the composition of the fuse cover and soften it, when the powder train will be ruined. Water in the cap will surely make it worthless.

Waterproofing

Inserting Caps in Explosive

The best location for a cap in a stick of explosive for farm blasting is in a hole in the side, about an inch and a half from one end. The best position for the cap at this point is at a slant that takes it in from the side toward the center, but as near longways, or parallel with the sides of the stick, as possible.



In cutting fuse from roll use sharp knife.



Taking one cap carefully from box.



Inserting fresh end of fuse in cap.



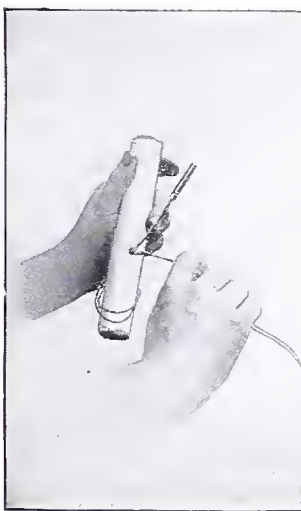
Crimping cap with the cap crimper.



Fuse tied firmly to stick with string.



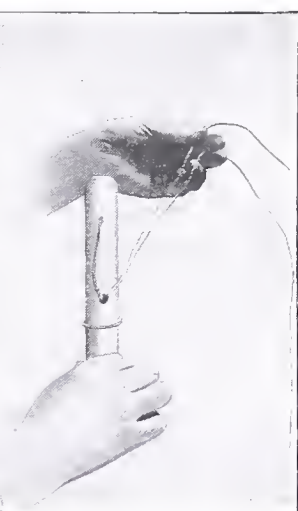
Electric Blasting—Pass the doubled fuze wires through a hole in stick of powder.



Loop the doubled end of fuze wires over end of stick.



Pull loop tight, bend wires at cap, punch slanting hole in stick high up and round to side a little.



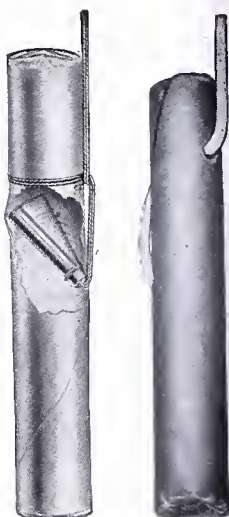
Insert cap in slanting hole to bend of wires, take up slack in wires. (Waterproof holes if ground is wet.)

Position of Cap in Stick

In other words, when making the hole for the cap in the explosive, make it with as long a slant down toward the other end of the stick as possible. There are reasons for this connected with superior or inferior detonation.

Another style of priming much used is to set the cap in a hole made in the end of the stick of explosive, and then to tie the paper about the fuse or wires. This is good so long as it is not damaged, but experience shows that the tamping stick often bends the fuse over sharply when the primed stick is pressed into the hole and sometimes even interferes with the cap itself. With side priming there is a cushion of the soft explosive between the end of the stick and cap. End priming always is good provided sufficient care is taken in loading to prevent disturbing or displacing the fuse or cap with tamping rod.

When all the explosive is removed from its stick wrappings, the cap must be inserted in the loose explosive. This should be done by making a hole, as in a stick. But it seldom pays to take all the explosive out of stick wrappings. Nearly always you can leave a half stick of explosive intact for the cap.



Bad priming.



A good crimp.

To make the hole for the cap use the handle of the cap crimper or a wooden punch just a little larger than the cap. The hole should be large enough to let the cap in without much pressing, but should leave no air space about the cap. The depth of the hole also is important. It should be just enough so that the entire cap can be buried in the explosive, but not any deeper. If it is deeper, the cap may be forced on down to the bottom, which will leave some of the fuse in contact with the explosive (may cause burning instead of exploding of powder), or the cap may be seated just inside the wrapping, leaving an air space at the inside end or bottom of the hole, which may lower the effectiveness of the explosive.

When the cap is seated in its hole in the side of the stick, the fuse will extend up along the stick past the near end. It must be tied in this position, so securely that the fuse and the cap will not be pulled back in handling or by rubbing against the side of the hole when the stick is pressed down. The best way to secure it is to wrap a strong string several times below the point where the cap is inserted, then give two or three wraps about the fuse, and pull tight and tie; or take two loops about the fuse and then several wraps about the stick.

Fastening Fuse to Explosive



Cutting stick in two—roll it under knife blade.

When the foregoing directions have been complied with you have a stick of explosive primed with a cap and fuse. It is ready to put in the hole in the rock or ground.

Loading Charges in Holes

You will need a tamping stick. This must be of wood, and had better be about the size of a stick of explosive, which usually will be $1\frac{1}{4}$ inches in diameter, except in case of blockhole blasting of boulders, when a smaller stick sometimes is needed to go in small drill holes. Never use a metal rod for tamping. Make sure that the hole is ready. It must be big enough to allow sticks of explosive to slide down easily (except in the case of small holes drilled in rock, when the explosive all must be taken out of the stick wrappings and crumbled and pressed into the hole).

Tamping rod Loose stones, sharp stones and roots that obstruct the hole should be removed with a bar or spoon scraper. This work must be completed before starting to load. If obstructions fall into the hole, after some of the explosive is in place, don't try to remove it by force. Make another hole at a safe distance from the first, put in another charge and fire it.

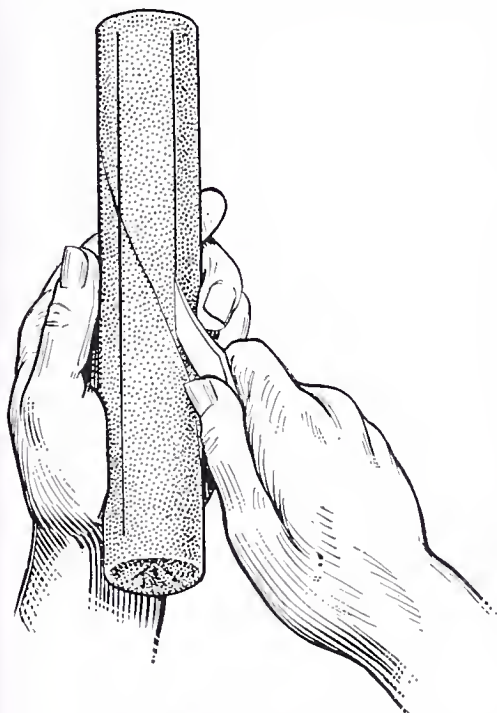
Measure the hole with your tamping stick and judge if there is space for the required charge at the right point. Nearly always a charge of explosives



The tamping rod should be of wood.

should be as much on a pile as possible. If one or 2 sticks are all the explosive

required, it usually will not hurt to put them end to end. But if 3 or more sticks are required, to put them end to end makes the charge too long, and places the force of the blast elsewhere than where it should be.



Slitting the paper wrapping of stick to let it swell to fill dry hole.

When your judgment tells you that the charge should be in a more or less round bulk, enlarge the hole at the point where the charge should be made. Sometimes this can be done by scraping it out at the bottom with a toe-bar or spoon-bar. Again, if much enlarging is required, it is well to use a small amount of explosive to secure it. This is called springing. To do this prime about a quarter of a stick as usual, and push it to the bottom of the hole. Use no tamping. After it is fired wait till the hole cools, and you will find a cavity large enough for your full charge.

It is better to avoid springing holes if you can, on account of the fact that the cavity often is enlarged too much, and the surrounding earth is loosened so much as to injure confinement. (See page 47 on detonation). A great deal can be done by scraping the small auger hole out to 2 or 3 inches in diameter at the bottom and then causing the

sticks to enlarge and fill the hole solidly. To accomplish this enlargement of sticks, slit their wrappings 3 or 4 places lengthwise, from end to end. Then press them home with the tamping stick. They will expand and shorten. Four to 6 sticks in this way can be got into the full length of two.

Still another way is to take the explosive entirely out of the stick wrappings, and with the help of a tin or paper tube, such, for instance, as calendars are mailed in, funnel it down to the bottom of the hole. But neither this method nor slitting the sticks is wise in wet holes. It is true that nitroglycerin powders will stand considerable water, but the safe rule in wet blasting is to leave the sticks intact. Ammonia powders or dynamites will not stand wetting inside the paper of the sticks without damage. (Never under any circumstances cut, break, unwrap or punch holes in explosive that is frozen. You invite an explosion in your hands when you do).

When there is more than one stick in the charge, place the primed stick on top of the others—put it in the hole last or next to last—when using the cap-and-fuse method of firing.

Be sure that all parts of the charge are in firm contact. It will not do to have air spaces, or dirt, or wrinkled paper between the sticks. While all the powder likely would go off under these conditions, it will not do as much work as it should.

The sticks of explosive may fit tightly in the holes. In that case do not ram or pound them, but press firmly against them, one at a time, with the tamping stick. Press the explosive into tight contact with the sides all round, at the bottom of the hole.

Tamping

Tamping is a necessity. The charge should be tightly confined. It is only in springing holes and sometimes in digging post holes that no tamping is advisable, and in ditching that the quantity needed is less.

Tamping

When the explosive is in place at the bottom of the hole, start the tamping by rolling in some loose ground. Keep the tamping stick working up and down to seat this ground against the explosive, though make no effort to get it tight till there is a few inches or so over the explosive. An exception to this rule is in the case of blockhole blasting of boulders and ledges, when damp clay tamping should be packed solid all the way down to the explosives. The rule for the least contents of tamping that will do good work is that it should be 6 or 7 times as deep as the hole measures in diameter.

If the tamping is less than this, the best results will not be secured, hence deep holes often are necessary for the sake of confinement of charge as well as to contain the amount of powder used.

Hold the fuse to one side with one hand while the tamping stick is worked with the other hand. Rake the dirt to the mouth of the hole and be careful to get in the hole only earth—not clods, sticks, grass, etc. Be very careful not to damage the cover of the fuse with the tamping stick.

Fill the hole to the top with tamping, and make it tight. The best material for tamping is moist clay. Tamping material always is better when made *wet* enough to ball. In fact, there isn't much better tamping than water itself in the hole, when it can be made to cover the charges deeply enough. Use the heaviest earth within reach, and if it is dry, better carry some water for wetting it.

Firing

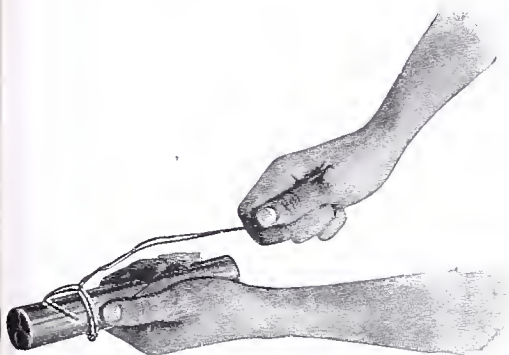
The free end of the fuse will stick out of the hole filled with tamping, say about 4 inches. Your remaining work is to set fire to the powder in the fuse, till it begins to spit continuously. Split the end of fuse with your pocket knife to make it light easily. Put the flaring head of a freshly scratched match against the powder exposed by the cut. (See page 50.)

Preparing Charges for Electric Firing (Making Primers)

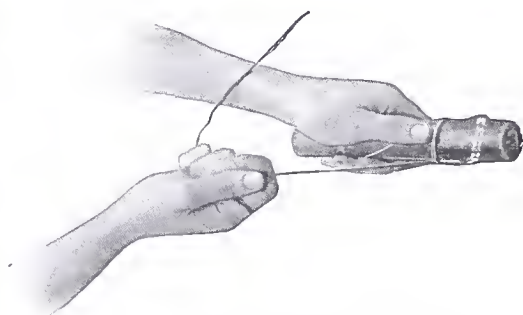
Up to this point in the directions for preparing charges the text has spoken only of caps and fuse. When the firing is to be done with an electric blasting machine instead of fuse, you must use electric blasting caps.

These come from the makers with the wires already fastened in them. (See pages 56 and 57.) They are ready to be inserted in the stick of explosive without any preparation such as ordinary caps and fuse require.

Make a slanting hole in the stick of explosive just as is described on pages 36 to 38. Into this insert the electric blasting cap, letting its wires project just as the fuse does when fuse is used. Then tie the wires to the stick with a string as fuse is tied, to prevent the cap from being pulled partly or entirely out of the hole.



Bad method of fastening wires.
It is better to tie them.



Bad position of cap in stick, and of cap wires.

It is a little difficult to tie the wires tight enough with a string to prevent slipping. Another way to fasten them securely is to pass the wires through the stick. To do it punch a hole straight through the stick of explosive about the middle. Double the wires about 6 inches back of the cap and pass the doubled end through this hole. Then loop the doubled ends from the other side back round the lower end of the stick. Take up the slack in the wires and you will have a sure fastening. The cap can be inserted in the stick at another point, in a slanting hole, just as described previously.

In fixing wires of electric blasting caps to sticks, avoid crossing them and avoid bending them sharply or in any manner that will break their insulating. If the insulating is broken it likely will cause a short circuit, which will result in a misfire. *Never take a half hitch about the stick with the wires.* Do not pull at the wires and the cap, because to do so may break the fine bridge wire that causes the cap to explode when the current goes through.

Load these primed sticks the same as is directed for fuse primed charges. Be careful to avoid rupturing the insulating on the wires with small stones in the hole or with the tamping rod.

The finishing of the tamping leaves two wires projecting from each hole. They must be connected with the blasting machine or other source of current with connecting wire and leading wire, in the manner described fully on pages 51 to 53. Further discussion is not needed at this point.

Some General Suggestions

In priming sticks of explosive with fuse and blasting cap, you must be careful to avoid permitting the fuse to touch the explosive. High explosives will burn like gasoline or coal-oil. They are very easily set on fire by sparks spitting from fuse. When they are burning the explosion will be very much weaker than it otherwise would be, and will give off noxious gases.

A very frequent cause of misfires is the bending, kinking and crooking of fuse. This is especially frequent when the cap is inserted in the center of the end of the stick of explosive and then carelessly forced over against the side of the hole by the tamping stick and tamping material. Keep the fuse straight, and never under any circumstances lace it through the stick of explosive. That is a sure cause of trouble.

If it becomes necessary to remove a cap from a primed stick of explosive, do it gently and carefully, and unless the cap and fuse are immediately to be inserted in another stick, destroy them both by lifting a shovelful of earth and putting the cap under the ground in the hole, after which light the fuse and go away.

It is better not to lift or carry the primed stick of explosive by the fuse or wires when it can be helped. When a practice of carrying primed sticks by the fuse is made, misfires and poor explosions will be caused, not every time, but often enough to make it wiser not to do so. The cap often is pulled back in spite of the tie string.

Where explosives that are subject to water damage are used in work that is wet, matters can be helped by making the sticks waterproof with tallow, paraffine or other suitable material. It is practicable to stop all the seams on the sticks, load and fire without delay, even with explosives that would be put out of business if the water got at the actual material instead of only at the wrappings of the sticks. Pay particular attention to waxing or tallowing the place where the cap and wires go into the stick.

When doing wet blasting, use every care to keep the outer end of the fuse from dropping into the water or from resting on damp ground. The inner wrappings of fuse and the powder train itself take up water like a blotter. On a very foggy day it is well to keep fuse in a closed box. Mist and rain, of course, will damage it.

Explosives and Blasting Supplies

The catalogs of manufacturers are not intended to give all the fundamental facts about and the differences between the various explosives. To do so would take too much space. They give the trade names and the measurements and weights of sticks and boxes, demanded by purchasers, and are prepared on the supposition that blasters and buyers of explosives know what they need. This bulletin includes explanations of the names under which blasting explosives are made and marketed, outlines their properties, and makes clear the work and conditions for which each grade is intended and suited.

Explosives

There are scores of different kinds of explosives made and used for blasting purposes, and many dozens of different names used for them. The most familiar name of any explosive in America is dynamite. Another familiar term is powder. Other names are farm powder, quarry

Names powder, contractor's powder, coal powder, stumping powder, Judson powder, gelatin, blasting gelatin, R. R. P., giant powder, blasting powder and dozens of others.

Nearly every one of the explosives designated by these names are made in several strengths, and in qualities to suit varying conditions. For this reason figures and other marks are attached to the names to distinguish the grades. In addition to this some of the names are used to designate not only one certain explosive but several widely different ones. This is particularly true of the names dynamite and powder. The selection of names in the preceding paragraph is made for illustrative purposes, and is not to be taken in any sense as a recommendation of those explosives for any purpose. The recommendations are given in detail on other pages.

All blasting explosives are not made from the same ingredients, and they differ a great deal in many other ways than in quality, as quality is generally understood. You can buy cornmeal that is good, bad or indifferent, but when

Differences you buy explosives you will find there are few which can be classed as of poor quality. Nearly every standard kind and grade is of excellent quality for some particular purpose and condition. And practically every one can be classed as of poor quality for conditions and purposes to which it is not suited.

Nor is the difference one of size of stick or grain, as the case may be, though this is one element. The main differences are ones of strength, quickness or speed of gases, sensitiveness, resistance to cold and to water, density, fumes and cost. Some explosives are suitable for wet work, and others only for dry work; some are adapted to blasting hard, tough rock, others to blasting ground only; some freeze when chilled a little; others can be exposed freely without freezing. And it should be noted that many of the better explosives of to-day have been developed during recent years and are comparatively new. The explosive to buy for any particular work is the best one on the market for all the conditions involved.

Black blasting powder has been known and used for several hundred years, and it is practically the same to-day as it has been for a long time. It is composed of saltpeter or nitrate of soda, sulphur and charcoal. It does not vary in strength, and varies little in other

Explosive properties.

Ingredients The dynamites and high explosive powders have little or no relation to black blasting powder. They depend for their explosive force on other explosive chemicals the best known of

which are nitroglycerin and ammonium nitrate. It is not necessary in this brief description to name additional explosive elements.

The first dynamite was made in Europe by mixing nitroglycerin with a light spongy earth, and packing the mixture in paper tubes as sticks of dynamite and powder are packed to-day. Nitroglycerin itself is a wonderfully efficient explosive when it can be controlled, but it is so dangerous and unstable that it must be mixed and treated to make it safe enough to handle.

As other explosive chemicals become better understood, it has been found of advantage to substitute materials that are explosive for the light earth used to absorb the nitroglycerin. And more than that, the nitroglycerin itself has been displaced to varying degrees in some of the powders and dynamites by ammonium nitrate and other materials. Few blasting explosives contain no nitroglycerin at all, but many contain only 4 or 5 per cent. of it. Each of these combinations of materials, or formula, has its own peculiarities in addition to variation in strength, all of which information it is well for a buyer and blaster to understand.

The explosives marketed as "straight dynamites" and "straight powders" are made from nitroglycerin. Those made from an ammonium nitrate base are called by many manufacturers "extra" dynamites and powders. Gelatin dynamites and blasting gelatin are nitroglycerin explosives in which the nitroglycerin has been combined with gun cotton. The various special mine, quarry, stumping, farm and other miscellaneous dynamites and high explosive powders on the market are not so named that their ingredients can be determined without a statement from their makers.

The power of an explosive and its violence are two different qualities. The power, or direct strength, is due to the volume of the gases. If a pound of a certain explosive gives, for instance, 1,000 cubic feet of gas when completely detonated or fired, while a pound of another explosive gives 500 cubic feet and a pound of a third gives 2,000, the lifting power of each explosive will be in direct proportion to its gas volume.

Strength and Quickness

But the violence of the gases depend, not on their volume, but on their speed. If they are comparatively slow in forming and in forcing their way out of their confinement they will break out large cracks and escape through them, pushing the material aside. If they are very fast or quick, they will grind and pulverize everything they come in contact with, and throw out the whole side of the confining material, but will not crack it so far.

The matter can be made clear by comparing a push with a blow of a hammer. Both may have equal power, but the effects on a block of wood, for instance, at the point where they are applied are very different. The push will move the object almost without marking it. The blow may move it, but it is sure to leave a mark of greater or less depth, depending on the nature of the hammer and its speed. A still better comparison, perhaps, is that between the blow of a sledge and of light hammer. It is possible to hit a blow of as much power or weight with one as with the other, but the material at the point where the blow lands with the light hammer will be badly dented, or maybe broken. The reason is that the light hammer moves with much greater speed.

In quarries blasters make use of these facts in order to get the rock broken out in pieces of the size preferred. When they want large pieces they use an explosive with sufficient power to break the rock, but, comparatively speaking with a slow speed of gases; when they want small pieces and much shattering, they use an explosive of the same or greater power but with swift and violent gas action.

For each result and for each material a certain power is required and a certain quickness of the gases is best. By way of illustration, take soil blasting for tillage purposes. There is no object in violently grinding the earth at one spot while surrounding earth that might be reached is left untouched. A proper explosive for this purpose is one that will have enough pulverizing action, that will lift and shake up the soil, and that extends its effects for long distances. For an example of the other extreme, take mud-capping rocks. For this work the explosive cannot be too violent in action. The gases, backed up by the rapidly yielding wall of air behind them, must strike the rock a crushing blow in the minimum of time.

Nitroglycerin and ammonia powders and dynamites, for all practical purposes, are of equal strengths when of equal markings. The strength is indicated accurately by percentage figures.

Nitroglycerin explosives are uniformly quicker and more violent in action than ammonium nitrate explosives, and the more nitroglycerin there is in the explosive the quicker it is. The ammonia explosives are not as quick, in any strength, as the corresponding nitroglycerin explosives. Therefore a 50% nitroglycerin powder is more violent than a 50% ammonia powder, and a 20% ammonia powder is much less violent than a 50% grade.

When the object is to shatter and reduce to fine fragments the material to be blasted, the proper explosive is a quick one, while when the object is to lift and shake up the material the best explosive is a slow one. (See table on page 47, also detailed recommendations on page 28.) But there are other factors that must be considered.

Nitroglycerin explosives resist water better than ammonia explosives, but if the cartridge wrappings are not broken or opened, ammonia dynamite or powder can be loaded in wet holes with entire satisfaction. The firing should not be delayed any longer after loading than necessary, and it is wise to plan the work so that it may be done at the longest within a half hour after loading. Storage in a damp place will weaken explosives, especially ammonia explosives.

Gelatin explosives resist water very well, and may be loaded in wet holes, or under water, with assurance that they will explode with their full power. Blasting gelatin is entirely water-resisting.

Explosives will freeze, and when in this condition are dangerous, and cannot be fired properly, if at all, with a cap of any kind. They *must* be thawed and they must be handled very carefully if they are to be used. On no account attempt to cut the wrappings, to break a stick, or to handle the frozen explosive in the ordinary way. (See pages 48 and 49 for directions for thawing.)

Regular nitroglycerin explosives are quickest to freeze. Others, known as "Low Freezing," will stand much lower temperatures without showing trouble in this respect.

Freezing Ammonium nitrate explosives also will freeze, but not quite so quickly as nitroglycerin explosives. They too are made on both regular and low freezing formulas. The low freezing ammonia will stand more cold than the low freezing nitroglycerin.

The regular explosives will freeze at temperatures of 45 to 50 degrees. The low freezing explosives will not freeze and become solid till the thermometer gets down to at least 25 degrees, and in practice many of them can be used right out in the open without any trouble when the temperature is down to zero and below. The length of time the powder is exposed to the cold has much to do with its freezing.

The safety point for both low-freezing explosives and regular explosives is not a matter of rule, but of watching the explosive. When high explosive

powder or dynamite is frozen, the sticks will be hard, and when it is partly frozen they usually will have a mottled appearance on outside of the paper wrappings. The hardness may only be in spots. When not frozen, the sticks should be a little soft all over. No explosives should be handled much, cut, punched, rubbed, broken or loaded when they are frozen. They cannot be exploded satisfactorily and such acts are dangerous.

In cold weather always use the low freezing grade of explosives, for the regular grades may freeze in the holes before they can be fired. It is a good plan to use the stronger caps, say No. 8 (see page 56) in cold weather. When a charge of explosive is chilled but not frozen it can be fired satisfactorily by a heavier impulse (blow and heat) than ordinary, such as a fresh No. 8 cap gives. The low freezing explosives do not differ in action from the regular explosives, and are just as efficient.

The gases of explosives naturally are more or less objectionable when breathed. Some of them are poisonous, others are merely disagreeable. When explosives are used out in the open the gases are taken up by the air so quickly that none of them give any serious trouble, though they do cause headaches. It is only in tunnels and deep shafts where the air is confined that the matter of fumes is important, not on farms.

Special explosives have been developed for tunnel and mine work, but they are not important in agricultural work. The only fact about fumes worth knowing in farm blasting is that nitroglycerin explosives either in the form of their gases or when absorbed through the skin will cause headache somewhat quicker than ammonia explosives. The so-called fumeless explosives always cost more than any ordinary dynamites and powders and are not suited to farm work. Farmers will do well to buy grades of explosives suited for their special purpose.

Other Properties Dynamites and most high explosive powders are light-colored materials that look like fine, sticky sawdust, and they always are packed in "sticks" made with cylinders of tough paper. These sticks vary in diameter and length. The standard is $1\frac{1}{4}$ inches in diameter and 8 inches long. This is the size carried in stock by dealers and in the magazines of the makers. You can get special sizes of sticks if you need a considerable quantity, varying from $\frac{7}{8}$ of an inch in diameter to 4 inches. Sizes other than the standard $1\frac{1}{4}$ by 8 inch may cost more per pound than the standard owing to higher packing cost.

Appearance of Explosives

Dynamites and high explosive powders are packed in wooden boxes containing 25 pounds or 50 pounds, as you prefer. A 50-pound box of 20% ammonia powder or dynamite will contain about 105, $1\frac{1}{4}$ by 8 inch sticks. If of 20% nitroglycerin, it will contain about 98 sticks. If of gelatin dynamite, or blasting gelatin, it will contain about 88 sticks.

A word should be said here about the cost of explosives. No quotations can be given because the prices vary in different parts of the country and from time to time. The ammonia products usually are cheapest. The cost of course follows the percentage strength, the low percentages cheaper and the high percentages dearer. Gelatin explosives cost about the same as straight nitroglycerin explosives. The special explosives for use in mines, tunnels, quarries, railroad construction work, etc., often cost more than the explosives recommended here for farm work.

In buying explosives look first to getting the one that is best suited to the work to be done, and aside from that the cheapest one. There

would be no object in using a straight nitroglycerin or a gelatin explosive when one of the ammonia farm powders would do the work, for the former explosive cost much more than the latter.

To avoid "explosive misfits" it is well to consider carefully the nature of the material to be blasted, the conditions of weather, water, etc., and the results wanted. The kind of explosives to use depends on these factors. Keeping in mind the facts mentioned in preceding paragraphs, the reader will see that there is a type of explosive made for almost every condition and kind of work, and will understand why one will not suit the work of another.

As the briefest and clearest way of giving general suggestions for the type of explosive best for different agricultural work, a table follows: (Detailed recommendations are given on pages 21 and 25.)

Explosives Recommended for Different Work

Stone blasting—mudcap.....	Straight nitroglycerin or ammonia dynamite, 50% or 60%.
Stone blasting—undermine...	To break, same as for mudcapping; to throw out, use any dynamite or powder of 20% strength.
Stone blasting—blockhole....	To shatter well, any high percentage dynamite or powder; to break into large pieces, 20% ammonia dynamite or powder.
Soil blasting—for subsoiling and for tree planting....	20% ammonia dynamite or powder.
Ditching—electric firing.....	20% to 40% ammonia explosives; (nitroglycerin is equally effective); in loose dry ground, high percentage nitroglycerin explosives.
Ditching—transmitted detonation	Straight nitroglycerin dynamite or powder, 50% strength.
Stump blasting—in medium and heavy soils, wet or dry	20% nitroglycerin or ammonia dynamite or powder.
Stump blasting—in dry sand and other light soil.....	50% nitroglycerin or ammonia dynamite or powder.

If you are in doubt as to the best explosives for your particular work it is well to write to the manufacturer you prefer, asking which of their grades and brands would be most suitable.

Detonation

It is well known that black powder is fired by a spark, and that dynamites and high explosive powders cannot be fired by a spark but require a shock and heat. It is not so well known that there are great differences in the nature and effect of the explosion of any powder or dynamite, due to variations in the way it is fired.

An explosion of powder or dynamite is the result of a very sudden creation of a great volume of gas from a smaller volume of powder. The kind and amount of gases produced by any

high explosives depend on the kind and amount of shock used to fire the charge, and on its confinement.

The effect of lighting a piece of unconfined dynamite with a piece of fuse without a cap on, is that the dynamite will burn fast without exploding and make a dense smoke which has a bad smell and produces severe headaches. This is simple combustion. If the piece of dynamite is confined closely and lighted in the same way it will explode, but will give off similar bad fumes. If a weak cap is used on the fuse, or the dynamite is set off by a fall, the dynamite will be partially detonated, and explode with considerable force, but it still will give off the bad fumes and smoke. The same piece of dynamite fired with a No. 6 or 8 cap will be completely detonated, and will explode with great violence and force, even when unconfined, except by air, and will give off very little smoke.

The last-named explosion is detonation. It is produced by a violent shock in connection with intense heat. Nitroglycerin is 5 times as strong as black blasting powder when exploded by fire, and 10 times as strong when detonated. This explains the enormous force given by detonation as compared to simple explosion.

But detonation itself is no set thing that always takes place the same. There is good, or complete, or full detonation, and there is partial detonation. In case of incomplete detonation, or any detonation at a less speed than the greatest for any particular explosive, the gases formed are not what they should be. For one thing, they are more noxious or poisonous. The more powerful and severe the blow delivered by the cap, the more quickly does the chemical action take place in the explosive. It is only when high explosives detonate with their greatest speed that their maximum power is generated.

Air spaces about the cap in the stick of explosive cushion its blow and weaken detonation. It is the nature of the initial detonation of the powder right around the cap which governs the nature of the explosion of the whole charge. A blaster should understand the importance of setting up *complete* detonation in order to get the greatest amount of force out of explosives. Sometimes explosives lose as much as 20% of their effectiveness when fired with weak caps. Lack of confinement has a similar effect. Sixty per cent. dynamite poorly detonated is less effective than 40% well detonated.

When explosives become chilled it is difficult to detonate them properly with the usual cap, hence the advisability of using a very strong cap in cold weather—a No. 8. Many of the holes are frequently loaded for some time before firing, and even if the powder is soft and normal while charging, it afterwards becomes somewhat chilled in the cold ground.

Throughout this and other bulletins in this series, the terms caps and electric blasting caps are used in speaking of the exploders used to fire the charges of dynamite or powder, although in the field and among manufacturers the same articles are called by the terms "detonators," or "electric exploders."

Cap Means
Detonator

Thawing Explosives

It has been pointed out (on page 45) that regular explosives chill or freeze at temperatures of 45 to 50 degrees. With the increase in the number of low freezing explosives that seldom need thawing, the necessity for doing the thawing on farms is not as frequent as it used to be.

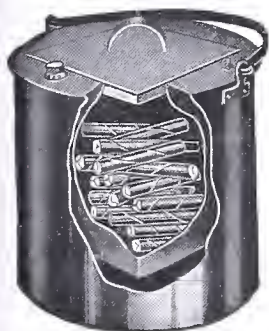
Frozen dynamites and powders are dangerous materials, and whenever the temperature is near the freezing point for them, the sticks should be

inspected before using to see if they show any of the hardness that indicates chilling. If so, handle them very carefully till they are thawed. Dynamites and high explosive powders will be a little soft to the pressure of your thumb when they are not frozen.

Frozen Explosive

Frozen explosives are dangerous because they are very much more easily exploded in the course of ordinary handling. They are more sensitive to friction and to blows of tools. The sticks may explode when dropped to the ground or floor, when sticks are broken in two, when wrappings are cut with a knife, when cap holes are punched with a stick, or when they are shoved into a hole with a tamping stick. At the same time they are so much less sensitive to the direct shock of a detonating cap that they cannot be fired properly with a cap. Therefore the rule must be laid down that frozen sticks of high explosives never must be cut or ruptured or used until they are thawed.

When nitroglycerin freezes it crystallizes, therefore the nitroglycerin in dynamite or powder tends to separate from its absorbing materials into small crystals. When the dynamite is thawed slowly with sticks lying on their sides, the nitroglycerin is reabsorbed as fast as it liquefies. But when thawed too fast, the nitroglycerin is liable to run out of the sticks before it is reabsorbed. Quick thawing will damage explosives a great deal more than they would be damaged by freezing followed by long, gradual thawing.



One type of thawer on the market.

Thawing is a dangerous operation when not done right. It probably is correct to state that more accidents with dynamite have occurred in the course of improper thawing than for all other reasons put together. At the same time proper thawing is entirely safe.

Two of the most frequent causes of accidents while thawing explosives are in putting the sticks into water or steam, and putting them on hot stoves or stones. Water, and especially hot water, forces the nitroglycerin out of the sticks. The free nitroglycerin goes to the bottom, and explodes at the time of the first increase in heat, or first light blow. When sticks of explosives are laid on hot material the nitroglycerin also runs from the paper wrappings and drops of it fall to the stone or metal. This almost always causes an explosion. At about 350 F. degrees of heat, which is only a little more than that of boiling water, the nitroglycerin will explode without a shock.

Causes of Accidental Explosions

Examine your explosives a day or so before you are ready to use them, and if they show that they are frozen, proceed to thaw them in one of the following ways: Use only a *DRY* warmth. Use no temperature higher than is comfortable to the hand, or the limit may be set at 100 or 110 degrees. Use no heat of any kind that cannot be controlled with certainty. If you do this you will be safe.

Safe Thawing

Every large maker of explosives will supply thawing apparatus that is safe. Sometimes this is a double kettle arranged so that the sticks of explosives can be placed in the inside vessel, while the outside vessel can be filled with warm water and a blanket can be spread over the top. Other more elaborate thawers consist of a vessel containing watertight tubes just big enough to hold

sticks of explosive, running through a space to be filled with warm water. The catalogs describe these ready-made thawers in detail.

Home-made thawers can be arranged with two buckets, one small enough to hang inside the other. Put the sticks inside the small one and warm water around the outside, in the big bucket. Another good way is to put a five-gallon can of warm water inside a barrel, or box, and pile the sticks of explosives in the barrel around the can. The top of the barrel should be covered with a blanket. Or put the water in the barrel and the explosives in a can or bucket. A small closet of course can be used instead of a barrel. A can of warm water can be set inside a magazine to keep the temperature up.

The old-fashioned manure pile method of thawing is reliable and safe, though a good deal of trouble. This consists in burying a box somewhat larger than a box of explosives in fresh horse manure, and placing inside it the box of explosives to be thawed. A foot or more of manure must cover the box, and a small pipe or tube should be inserted for ventilation. The manure must be fresh. Allow at least 10 hours to thaw a box of dynamite or powder in this way. Twenty hours is better.

The box of explosives can be taken into any warm place that is dry, but if this is a building you must take your own risk of fire and accident. Watch the box and the sticks to see if the freezing and thawing causes the sticks to leak free nitroglycerin. If any of this leaks out of the stick and gets on the floor it must be washed up according to directions in paragraphs on storage. (Pages 59 and 60.) The sticks of explosives had better be piled irregularly rather than in tiers, for thawing. They will rise in temperature quicker in this way. They always must lie on their sides rather than stand on end.

Sticks on Sides

Electric and Fuse Firing

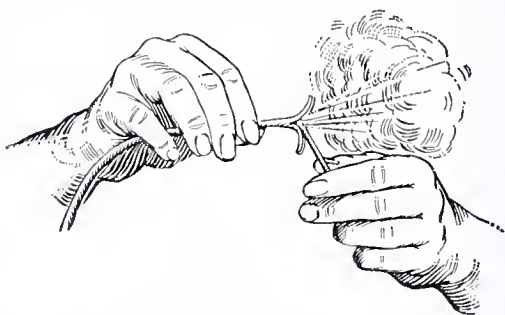
The very best way to light fuse is to split the end for an inch or less, and stick the burning head of a freshly scratched match right against the exposed powder at the head of the split. This will light the fuse even in a strong wind.

Where there are very many fuses to light in succession, as in subsoiling, it sometimes is of advantage to use a gasoline or other torch, holding

Fuse and Cap Firing

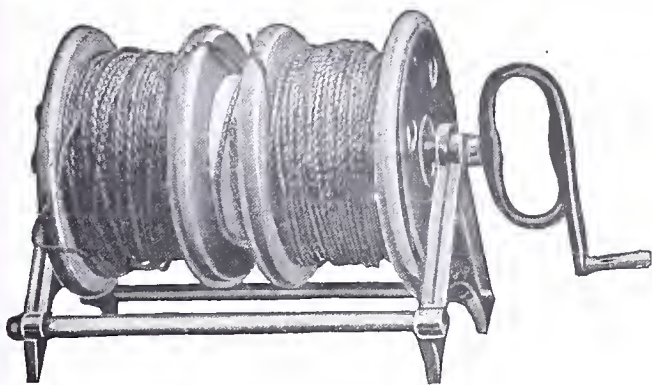
the hot flame under the fuse for an instant. Whatever the method, do not leave till you see the fuse spitting sparks and smoke swiftly and regularly. Further discussion of fuse firing, except as to its adaptations, is not needed.

Farmers who have only a few stones or stumps to blast, or who are planting a few trees or doing a little subsoiling, will not need any other method of firing than by caps and fuse. Ditch blasting in ground not water-soaked demands electrical firing, while the blasting of large stumps, particularly if green, and in sandy soil, as well as the blasting of large rocks, is made easier and cheaper by electrical firing. For large amounts of almost any blasting except that of tree beds, subsoiling and very small stumps and isolated small



Electric Firing

boulders, the purchase of an electric blasting machine and the necessary wires is justified by the advantages of the electric methods of firing.



A good reel for leading wire.

make a perfect ditch. In stump blasting several small charges very often will take a stump out better than one large charge, and in orchard, and garden subsoiling the simultaneous blasts frequently are of advantage.

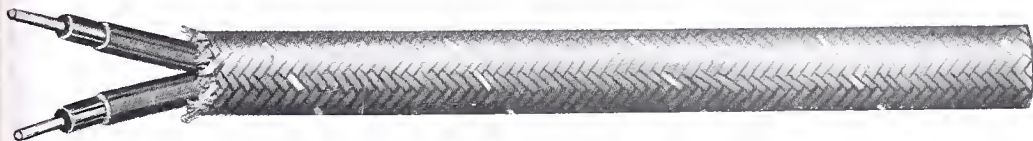
Electric firing is more certain when the charges are under water. The danger from misfires due to moisture as well as from some other cause is reduced. Should misfire occur, you are safe in going to the charges as soon as the wire is disconnected from the blasting machine. With a fuse you must wait some hours to be safe. When several charges, as for instance, several boulder blasts are to be fired, you can make one trip to safety do for the lot, instead of having to travel back and forward for each shot. Finally, the intelligent and careful use of electric firing, with its possibilities of two or more small charges doing the work of one large one, and its other economies, will save considerable explosives.

All the makers of explosives supply electric blasting machines. The machines are small boxes of wood or metal, containing a modified magneto with a handle on top that you either push down or pull up, depending on the make of machine, to operate and to fire the charges. The machines are made in various sizes and capacities to fire 3, 10, 30, or more charges at once. The 10 charge machine weighs about 10 pounds. Full directions for operating and caring for the machines always accompany them.

For electric firing, in addition to the machine, you will need electric blasting caps, connecting wire and leading wire. The leading wire is copper wire large

The primary reason for the superiority of electric firing over fuse firing is that several charges may be exploded at once; the different charges will increase the efficiency of each other. Thus in ditching,

Advantages you can fire many charges in a row and



Duplex Leading Wire. (Actual size.)

enough to carry the amount of current required for the number of charges to be fired simultaneously. It is covered with insulating material, and is made strong and durable to stand much use. To make the circuit from the blasting machine to and through the charges and back again, you must have two strands of leading wire. It comes from the

Wiring

explosive makers in single-strand form, which must be doubled, and in what they call duplex form, which has two strands of insulated wire twisted together or wrapped together under one cover.

The two small copper wires that are fixed in the electric blasting caps (see page 56) should be long enough to reach out of the holes. They may

Electric Blasting Caps

be bought in a variety of lengths, but 4 or 6 feet are regarded as

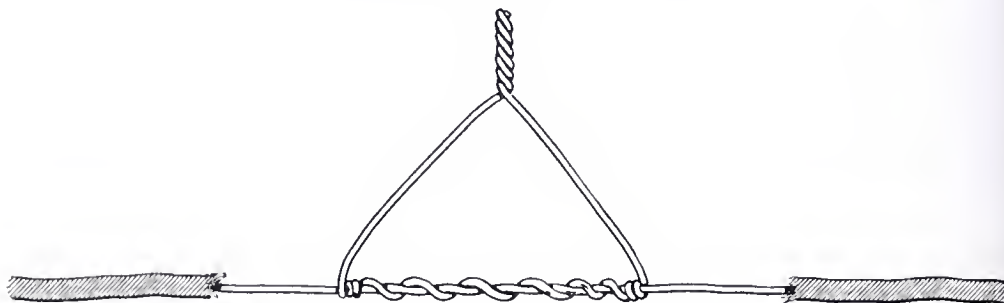
standard. If the charges are close enough together so the wires can be connected, no connecting wire will be needed; but whenever the distance between is more, the charges must be connected, and connecting wire is the right thing to do it with. There is no particular limit for the distance between charges that may be connected for firing together, up to 25 feet or more.



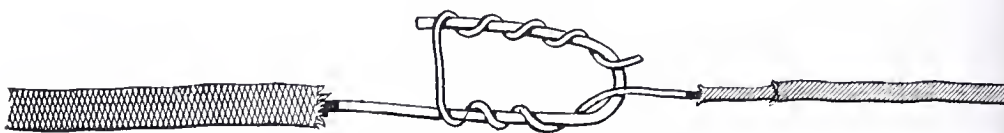
Connecting wire comes on spools.



A very bad connection—a cause of misfires.



Good connection for electric cap wires



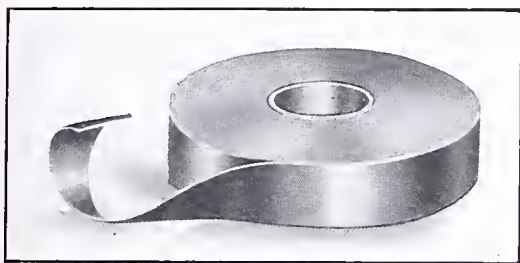
Good connection for small cap wires and large leading wire.

The diagrams in these pages will show how to make electric wire connections. Cut away the insulating on the wire ends and wrap the ends together tight. Wrap them for two inches. Looping the wires will not do. Be careful to scrape with a knife or stone the wire ends to make them bright before wrapping them together. Corroded or dirty connections are a cause of misfires.

Wire Connections

If the leading wire gets broken and must be spliced, solder the connection after wrapping the ends together, then wrap the joint with tape to

insulate it. Ordinary tire-tape is good, but a better way is to wrap the joints with special rubber tape underneath and to cover this with the tire-tape.



Tape for wrapping joints and broken insulating.

When only one charge is to be fired, connect the ends of the 2 strands of the leading wire to the 2 electric blasting cap wires and connect the other leading wire end to the blasting machine posts. The connection with the electrical blasting machine should be made the last thing before firing, after you are sure* that the charges are all ready and after every person and animal is out of the way of the flying pieces.

When the blast is all connected together ready to fire, except attaching the leading wire to the machine, give the handle of the machine one or two light strokes, to make sure that it is working smoothly and to charge the magnets. Then attach the leading wires to the binding posts on the machine, making sure that both the binding posts and the wires are bright and clean where they come together. Raise the handle of the machine to its full height and push it down with speed. When the handle starts on its downward stroke, the pinion immediately clutches the armature and starts the generation of current. The current, growing stronger as the stroke proceeds, causes considerable resistance toward the end of the stroke. The current generated is directly in proportion to the speed with which the handle is pushed down, especially just before reaching the bottom. Any let up toward the bottom will cause a drop in the current and may result in misfires. Therefore, make it an invariable rule, whether the shot be large or small, to bang the handle down hard and carry the stroke with all possible speed to the bottom. Try to knock the bottom out of the box. Machines which operate by the twisting of a handle must be handled equally quick.



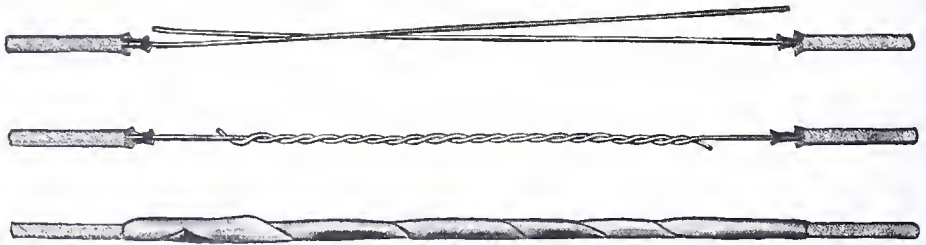
Very best wire connection, ready for soldering if need be. (Excellent for leading wire.)

When more than one charge is to be fired the different charges must be connected together. The diagrams will help you to understand how this should be done. For nearly all agricultural blasting the connection in one series is the best—that is, connecting each charge to the next one and so on until they are all joined, with one loose electric blasting cap wire from the two end charges of the series. (See diagram A and D, page 54.)

Once in a while, where the series is long and the charges are in a line, you can arrange to have the 2 loose wires at the same end of the series by making the connection, not to each next charge in the row, but to the one beyond and at the farther end doubling back and connecting the missed charge. Do not use this method where it involves many splices with connecting wire.

Connections in parallel sometimes are desirable in the case of ditches, or other extensive blasting. To make them run a piece of wire away from one leading wire strand along the lines of charges and connect one wire to each charge. Then run another similar piece of connecting wire connected to the other strand of leading wire, and attach to it the other cap wire of each charge.

But to fire charges by means of parallel connections takes so much electric current that a blasting machine cannot be used. Generally speaking, parallel



Method of wrapping wires together to make electrical joint, and of taping joint.

connections require current from an electric light or power plant. If your work is such that the charges cannot be connected in series or that parallel connections are desirable, it is well to communicate with an expert or authority on electricity for special suggestions and advice as to how best to fire your charges.

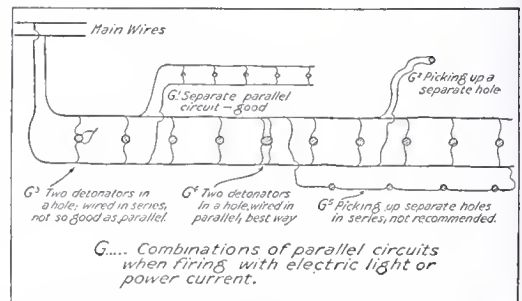
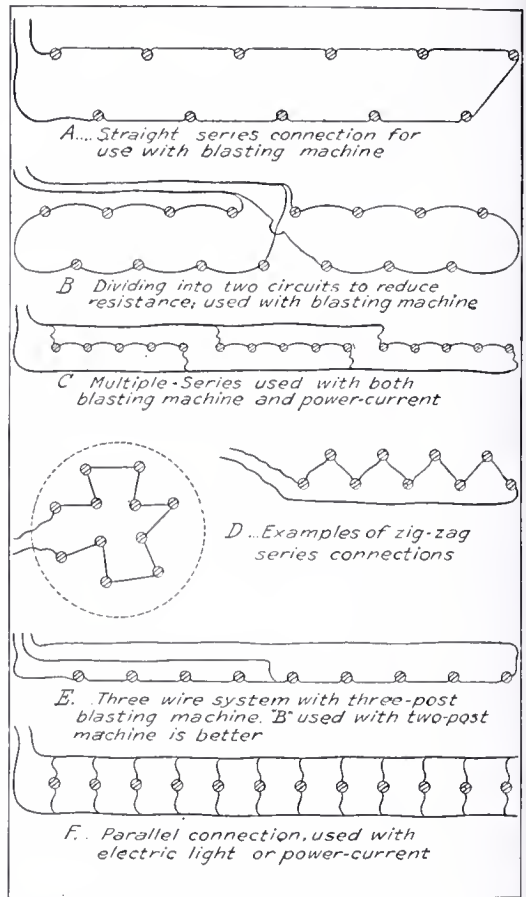
In a bulletin of this size it is impossible to give a comprehensive statement of

Current electric firing. But **Required** to give some idea, it can be stated

that an electric blasting cap requires 1 to 1½ amperes to insure firing. This amount of current will fire one cap or many in a series. To force this amount of current through the wires requires a certain voltage, the amount depending on the size and length of all the wires, and on the joints. One bad or poorly wrapped joint will increase the resistance of the circuit more than several caps. The voltage of the current required to fire any circuit usually can be computed by an expert when the details of the wiring system are explained to him.

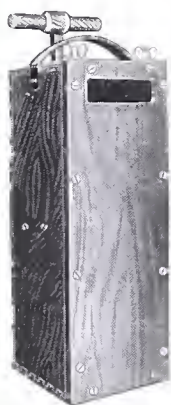
When charges are connected in parallel, instead of series, or in multiple series (see diagram C), each circuit requires 1 to 1½ amperes of current. That is, each cap requires 1 to 1½ amperes when connected in parallel. The voltage required, of course, depends on the resistance of the wires. A very much greater current than of 1 to 1½ amperes will do no harm; in fact it is desirable.

Electric blasting machines are constructed to give a sufficient amperage and voltage for



Ways of connecting up charges for electric firing.

firing properly the number of caps specified as the capacity of the machine when connected in a series. If too many caps, or more than usual wiring is connected to any machine, misfires will result. Other current can be used in place of that supplied by a machine, provided it has enough and not too much amperage and voltage. Too great a current will burn out wires without firing all the charges. Too little current sometimes will do the same, or it may do nothing. In emergencies dry cells or wet batteries can be used by skillful operators to fire a few charges, when great care is taken to have the wiring arranged for the purpose. Before attempting to fire charges with batteries of any kind, learn the amperage and voltage of their output and see that your shots come within their limits. The use of batteries is more expensive than the use of electric blasting machines.



Two post electric blasting machine—push down type.

Bare connections at the charges or back along the leading wire should be raised off the ground by stones, sticks or piles of dirt placed under insulated parts of the wires at each side of the splice. During a thunder storm, do not stand near any of the charges that have been connected. Avoid dragging the leading wire over bare or rough ground as much as possible, and particularly avoid kinking it. Be careful not to break or tear or scratch the insulating of any wires.

Do not attempt to fire through a long length of leading wire wound in a coil or on a reel. The induction, leakage or short circuit of current in the coil of wire causes the blasting machine to deliver a slow discharge, which is fatal to proper firing. Leading wire that is watersoaked or that is covered with mud will lose a considerable part of its current.

Misfires

Nearly half of the accidents noted each year in blasting operations are the result of attempting to examine misfires too soon. If misfires occur with fuse firing, stay away from the shot at least 2 hours. It is better to wait until the next day, for the spark may linger 24 hours and still cause an explosion. (See page 42.) Rock and stump misfires are to be avoided especially. When you are firing the charges electrically, you may approach the shot with entire safety as soon as the lead wire is disconnected from the blasting machine.

Misfires are due to the following named causes. The remedies for them are care in preparing the charges and in loading, the details of which are given in the proper chapters.

With cap and fuse firing, misfires are caused by having the end of fuse pulled back a little from the bottom of the cap, by crimping the fuse too tightly with a groove crimp and shutting off the spark, by damp or wet fuse, especially at the end of the cap, by defective cap, by the cap getting pulled out of the explosive, by kinked, damaged, broken or pinched fuse, by failure to light fuse. A great many misfires were never fired at all. With electric firing the reasons for misfires may be damaged wires in the hole, causing short circuits, defective caps, overloaded blasting machine, cap pulled out of explosive, bad wire connection at some point, or broken wire.

If you find after due time that for some reason the charge cannot be fired by lighting the old fuse or by sending current through the wires, you must deal with a real misfire.

The best thing to do is to put in another, lighter charge in a new hole made 6 to 12 inches of the original one. The explosion of the new charge will explode

the old one. Never touch the tamping in the old hole unless you know just how deep it is, or how many inches of it there are above the charge. Once in a while the tamping may be dug out of a blockhole misfire. It seldom pays to do this in stump blasting, and never in ditching, or soil blasting. At best it is a dangerous operation. Mudcap charges can be opened and new primers inserted without danger or difficulty. This should be done by removing part of the mud at another point, and inserting a new cap and fuse, or electric blasting cap, as the case may be.

Cap (Detonators)

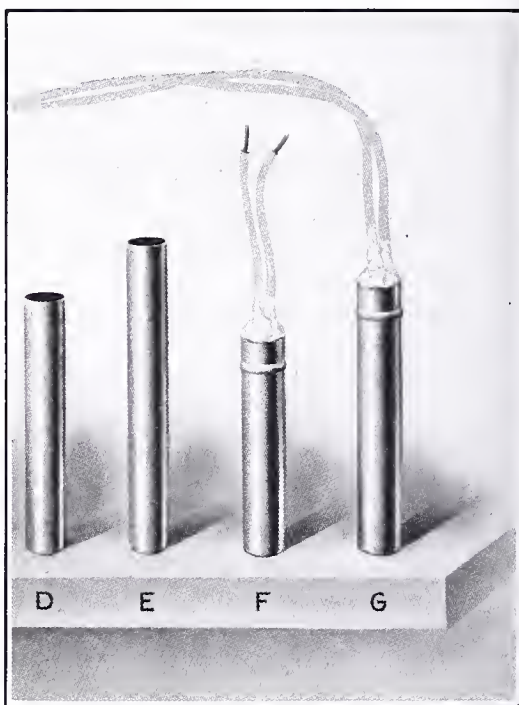
Blasting caps are little copper tubes closed at one end, $1\frac{1}{2}$ to 2 inches long and something less than a quarter of an inch in diameter. At the bottom is placed several grains of a high explosive that is very powerful and exceedingly sensitive to heat, shock and friction. This high explosive usually is fulminate of mercury, but often is other material. They are packed in small tin boxes, open end up, usually 100 to the box.

The purpose of the blasting cap is to supply the shock and heat necessary to detonate the charge of dynamite or powder to be fired. If it were not for safety in handling blasting explosives, they all could be made as sensitive as the material in the caps. But such explosives would be impossible to handle without accident. In fact, it would be impossible to handle the little bit of explosive in the caps if it was not protected by the copper shells. Even at that caps must be kept free from jars and from heat and sparks to avoid premature explosion.

The strength of caps is carefully regulated by the makers to fire the dynamites and powders on the market. The explosive material with which the caps are loaded is such as will deliver a shock and a degree of heat of the strength and violence required. The caps are numbered according to strength. All dynamites and powders used for agricultural blasting require at least a No. 6 cap. If they are chilled a little, but not frozen, they require No. 8. It is the part of wisdom to use No. 8 caps all the time if you can get them. They give you a margin of strength should moisture or other causes weaken them in storage.

Blasting caps must be used with fuse. And before they are inserted in the stick of explosive they must be fixed to the fuse properly. (See pages 36 to 38.) It is the spark which travels down the fuse that fires the cap.

Electric blasting caps are made on the same principle as ordinary blasting caps. They have the copper tube, the explosive at the bottom, etc., but they differ in the way this explosive is fired. Instead of by a powder spark they are fired by a red-hot wire that is heated by an electric current.

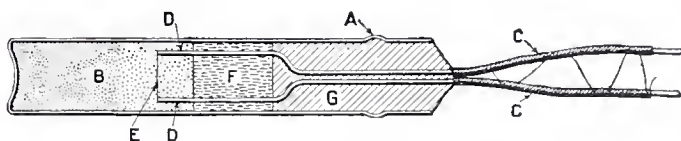


D and E are ordinary blasting caps; F and G are electric blasting caps, often called fuzes.



Electric blasting cap or fuze.

Every electric blasting cap has fitted in it 2 small copper wires, which must be considered part of the cap. Down near the bottom of the cap is a delicate bridge of finer wire. The entire arrangement is held in adjustment and sealed by a casting of sulphur-like substance.

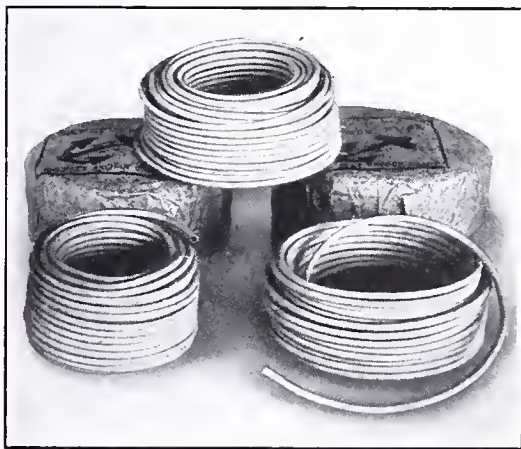


The interior construction of an electric blasting cap or fuze.

For fuse blasting you must use regular blasting caps, and for electric blasting you must use electric blasting caps. It is impossible to substitute one for the other. Never pull at the wires in an electric cap. It is dangerous and may loosen or throw out of adjustment the arrangement of wires inside. And never try to dig out the wires of an electric cap or to dig or to punch the explosive in the bottom of a blasting cap.

Fuse (Safety Fuse)

Fuse is used for firing black blasting powder and for firing dynamite and high explosive powders through the medium of a cap. It is made by enclosing within a covering a train of special black powder and an inflammable cotton string. The spark runs down this powder train.



Fuse as it comes in rolls.

The powder used in fuse is specially made for the purpose, is pulverized and is highly compressed by the covering of the fuse. The covering itself is made of varying materials, depending on the conditions under which the fuse is to be used. For dry work it is only enough to hold the powder in place and to keep the powder train from getting broken. For damp and wet work it is made waterproof by increasing the number of layers in the covering and by adding varnish, coal tar, as other waterproofing material.

There are many brands of fuse on the market. In buying fuse you must bear in mind the character of your work. For work that is entirely dry you can use ordinary cotton or hemp fuse with satisfaction, if it is large enough to fit a blasting cap snugly.

Grades
For work in damp ground, use a fuse in which the cotton or hemp is covered with one layer of waterproof tape or other material. This is called single-tape grade or may be known by brand name only. For work where the ground is wet, such as in stump and stone blasting in damp or wet weather, use a double-covered fuse—fuse that has two layers of tape or other material over the cotton

covering and waterproofing material added. For work where water covers the charges it is best to use fuse with three layers of tape or other material and full waterproofing. This is called triple-tape fuse or may have special brand names. When buying fuse for general farm work, it is well to get a waterproof grade, since it can be used for both wet and dry work.

Most reliable fuse burns about 2 feet per minute when in perfect condition.

Rate of Burning If it becomes damp, it burns much slower. Cases have been known where the spark smoldered in damp fuse for hours without traveling more than a few inches. Another source of uncertainty is where fuse has been pinched. It may take the spark a minute or an hour or a day to get past the pinched point.

When fuse is cold, it is hard and brittle, and may crack open when unrolled. If it gets too warm, its waterproofing material may penetrate to the powder train inside and ruin it; or the covering may first soften and then harden, in this condition breaking as though cold when unrolled. If grease is allowed on the cover it may combine with the waterproofing and ruin the powder inside.

Handling Explosives

Dynamites and powders in boxes can be hauled freely in spring wagons. You should see that no bolt heads or other metal parts project from the wagon boxes to strike the boxes of explosives. Sweep all dirt out of the wagon. Have the beds clean or covered with straw or blankets.

Go over your wagon and harness before you load dynamite to make sure they will not break down while you have the explosive aboard. Be sure you have the hitching straps or tie-ropes along, and do not leave the horses standing without tying them securely. Break no colts while hauling explosives. If you use a motor, stop it and set the brake tight before you leave the load. In driving through a town stay away from dangerous crossings.

Keep the sticks of explosive in their original boxes until you are ready to use them. Don't have them around loose. In carrying them to the field, use a wood basket or a box and not a metal bucket. Always protect explosives from all possibility of being reached by falling sparks or from match heads or other source of fire. Rain, hot sun and the like must be kept away from explosives. Use care to lay sticks or set the boxes or baskets containing explosives where they will not fall down, be blown over by wind or knocked over by careless people or by animals. Cattle will eat sticks of dynamite, or powder, because of their sweet and salty taste. The explosive will make them sick, sometimes kill them.

Since nitroglycerin often will cause headache when absorbed through the skin it is best to wear gloves when handling the sticks. For this same reason some people punch holes for caps in the sticks with a piece of wood rather than with the handle of the cap crimper.

Caps should not be carried in the same basket or box as explosive, but should be carried separately. Take only enough along to do the work in view and carry them in the tin boxes they come in. Many serious accidents have been caused by blasters having loose caps in their pockets during work or afterwards. Sooner or later a chance jar is likely to set them off. When several caps have been taken out of the little tin box in which they come the rest will be loose and will rattle about. This should be stopped by filling up the empty space with paper.

The handling of caps is not dangerous provided you do it intelligently and with care. *Keep them safe from any jars or heat.* You can sometimes do

Handling

many foolish things with dynamite and powder without serious results to yourself, but not with caps. Letting a cap fall to the ground or floor likely will cause it to explode. For this reason you should keep the caps and explosives apart, in hauling, storing, and handling, bringing them together only at the last minute before you prepare the charge to be loaded in the hole. One cap can produce an explosion powerful enough to tear your hands off.

Electric blasting caps must be handled with the same care as regular blasting caps. All caps must be protected from dampness during handling. No trouble will be experienced if you use common sense at every turn, but thoughtlessness and carelessness in the handling of explosives will cause disaster. Bear in mind that when an accident happens with an explosive there is no time to save yourself, and no afterthought will prevent serious injury to you. Forethought is the thing with explosives. In an explosive you are handling an enormous strength. The fact that it occupies small bulk now should not interfere with your imagining it as an enormous engine with power enough to crush you easily, but under entire control if you do your part right.

Storing Explosives and Supplies

The storing of dynamites and powders on farms offers no serious problems, though it may call for some shifting of arrangements to meet proper requirements. The explosive must be kept dry. They should be kept cool. This means that any ordinary temperature of the air is all right, except that in hot weather the room where the explosive is kept should not get warmer than 80 or 90 degrees. If it is properly ventilated day and night it will not. Probably the best common storage place for explosive is in an outbuilding under the floor of which the air circulates freely and with a ceiling between the room and the roof. It should be strong, and should be provided with a lock. A responsible person should have charge of the key at all times.

The explosive should not be kept in a garret, because the hot sun beating down on a roof will raise the temperature under the roof away past the 100 degree mark.

Dampness is injurious to explosives, as noted on page 34, and dynamites and powders must be kept where moist air will not surround them. The ideal storage would be fireproof, but since this is out of the question on the average farm, the best that can be done in that respect is to guard against fire. It is well to make sure that the explosive is out of reach of any stray or malicious bullet that might be fired into it.

Look to your insurance policies and see whether they provide against the storage of explosives in any of your buildings. Store the explosive in a building not covered by the insurance.

Where large quantities of explosives are to be stored as a regular thing, or for any length of time, it is advisable to consult the makers of explosives or others experienced in their handling in regard to the location and construction of a magazine. A magazine can be set up cheaply and can be made fireproof, bullet proof, thief proof, well ventilated, dry and safe in every way. It should be built of brick. Any explosive maker will furnish plans without charge. In any case explosives should be stored at least 50 yards away from any other buildings and from roads or railroads.

Magazines

Blasting caps of any kind must not be stored with dynamite or powder.

Fuse is not explosive and can be stored with dynamite or powder.

Caps

Blasting caps are even more subject to damage by moisture than explosive and must be stored accordingly. Caps must not be allowed to become heated.

A statement of the ways in which explosive deteriorates will help in selecting a proper storage place for it. In temperatures higher than 80 degrees troubles may begin. Long continued temperatures of 90 to 100 degrees may cause the nitroglycerin to leak out of the absorbing material and to gather inside the wrapping on the lower side of the sticks, or may even cause it to leak out of the wrappings through the

Deterioration

boxes and to the floor.

Strict watch should be kept of the sticks and the boxes to catch any such condition. If leakage occurs, turn the explosive over and reduce the temperature. Burn the empty boxes one or two at a time out away from buildings, and scrub the floor where the leakage occurred with a strong solution of sal soda. This will decompose the nitroglycerin. If it becomes necessary to destroy a little explosive without detonating it, the job can be done by immersing it until dissolved in such a solution, stirring it gently with a wood paddle.

If the sticks feel smeary it is possible they are leaking. The test is to lay them on white paper for a little while. If they are leaking they will stain the paper, otherwise not.

At a temperature of 105 degrees nitroglycerin explosives will lose 10% of their strength in a few days by evaporation. Repeated freezing and thawing is bad for explosives, especially if the thawing is rapid. Slow thawing will not damage them much. After explosive once is frozen and thawed, it will freeze much easier again.

When stored for many months explosives are liable to decomposition of some of their elements, especially if they get damp or too warm. One of the marks of this is greenish stains inside the stick wrappings. No length of time can be stated for the keeping of explosives, because it practically all depends on conditions. Under favorable conditions most dynamites and powders will remain in good shape for years. Again, a month of improper storage will ruin them and make them dangerous to handle. They develop troubles sooner in the light than in the dark.

Deteriorated explosives are likely to be dangerous—far more so than normal explosive. Keep watch over what you have in stock. Maintain proper conditions as far as possible, but if they show troubles do not hesitate to condemn them.

Shipping Explosives

The shipping of high explosives is controlled by the Interstate Commerce Commission, and the rules and regulations are very strict and rigid. Most of them are embodied in an Act of Congress of March 4, 1909, and violations are punishable with fines of not more than \$2,000, or imprisonment for not more than eighteen months, or both. The person making the shipment is responsible.

A copy of the rules and regulations can be secured from the Bureau of Explosives, Underwood Building, New York City, or can be read at any freight station where there is an agent.

The rules provide that no explosives (other than certain exceptions named) shall be carried on any train, boat, trolley, or other vehicle carrying passengers

for hire, and that no explosives under deceptive or false markings or understanding shall be delivered to a common carrier; and further, that all other regulations shall be complied with.

In shipping by railroad no caps or detonators of any kind can be sent in the same car with explosives. In practice the railroads usually send them by another train, which works out to be another day in the cases of nearly all shipments. This is responsible for some delay in delivery of explosive shipments. Do not expect to have explosives come through as quickly as you would other freight.

Explosives cannot be shipped by express or by mail, but are sent by freight, the same as groceries or dry goods. The railroad company is required to place the packages in a certain way inside the car and to brace them with lumber. In case of car-lot shipments the shipper must furnish this lumber and do the bracing.

The regulations provide that railroads must have 24 hours' notice of shipment of explosives, *and that shipments must be removed from the receiving station within 24 hours of their arrival there.* The packages must be plainly stenciled with the name of shipper and consignee, and bills of lading must conform with certain specifications.

Empty boxes which once have contained explosives must never again be used for shipments of any kind. Farmers who have attempted to ship vegetables or other farm products in such boxes have unwittingly gotten themselves into trouble on account of this regulation more than once.

Danger and Safety

Modern explosives have been developed to the point where they need not be feared by anyone who handles them intelligently. Speaking in a comparative way, they may be used with no greater dangers than there is in the using of horses, mowers, traction engines, sawmills, or other farm equipment, or than there is in using shotguns or rifles.

The general use of explosives on farms is so new that many people distrust them more because of their newness than from a clear understanding of any actual dangers their use may hold. A review of what the dangers are may help users of explosives to avoid them, and may help to build up the reader's belief in the *safety* of explosives.

There is some danger in the handling and transporting of explosives, but it depends very largely on the exposure of the dynamite or powder to heat, flame, sparks, blows and friction. The directions say to keep explosives dry, to keep them at a temperature less than 90 or 100 degrees F., to keep them safe from sparks, and to avoid blows and shocks. If these directions are followed there will be few accidents.

Probably the most common cause of accidents with explosives lies in violation of some of these primary rules while thawing frozen sticks of dynamite or powder. Freezing makes the high explosive less sensitive to the simple direct shock of a blasting cap, unaccompanied, as it is, by any friction. But at the same time freezing makes the explosive more sensitive to friction in any form.

For this reason, though a frozen stick of dynamite cannot be fired properly by a blasting cap, it is very likely to be fired prematurely by a chance light blow from any object touching it, by your slitting the wrapping paper with a knife, by breaking the stick in two, or by attempting to punch a hole into it to insert a cap. (These operations are entirely safe when the explosive is normal.) If the stick is dipped in warm water or exposed to steam, or is laid on anything which is warmer than about 125 degrees, free nitroglycerin likely will leak out

and fall in drops. And one drop of nitroglycerin falling only a few inches may be exploded itself and may explode all dynamite that is near it.

Throughout the entire course of handling the explosive, from the freight station to the hole in the stone or the ground, you should remember the five cautions which will be repeated: Keep it dry, keep it cool, keep it away from sparks and flame, and keep it safe from blows and friction. Be careful—as careful as you would in driving a big automobile or a traction engine. Then you will be secure from any accidents, and explosives will be entirely safe to handle.

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